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Lemchen

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[54] **SCANNING DEVICE OR METHODOLOGY TO PRODUCE AN IMAGE INCORPORATING CORRELATED SUPERFICIAL, THREE DIMENSIONAL SURFACE AND X-RAY IMAGES AND MEASUREMENTS OF AN OBJECT**

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[51] **Int. Cl.**[7] **A61B 6/00**

[52] **U.S. Cl.** **600/407**

[58] **Field of Search** 600/407, 440, 600/443, 444, 445, 447; 250/363.04, 363.03

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5,299,253	3/1994	Wessels .
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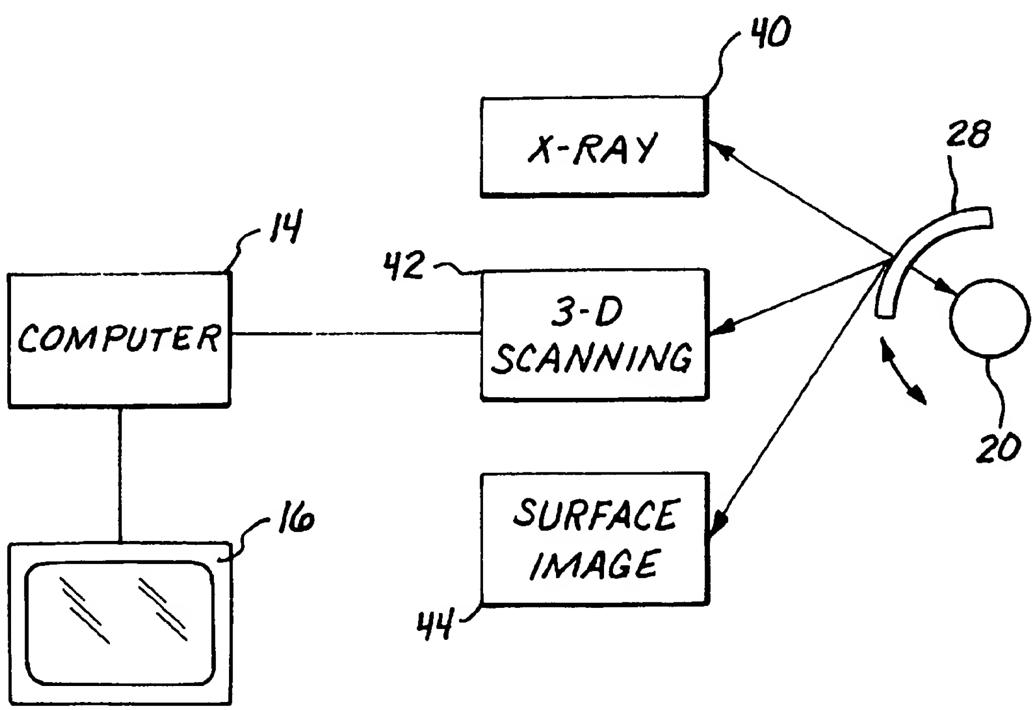
[57] **ABSTRACT**

A conventional digital panoramic radiographic unit includes sonic or optical three dimensional scanning detector and a color video detector so that when the panoramic x-ray data is obtained, three dimensional contour of the surface of the patient's skin and the outward visual appearance of the patient's skin are also obtained as correlated data sets. The correlated data sets are then stored within a computer system as three sets of simultaneously or near simultaneously taken correlated data. The correlated data is then deconvolved to form a two-dimensional image of the tooth and jaw structure of patient as correlated to the patient's jaw and lip contours and visual appearance from a selected viewpoint.

15 Claims, 3 Drawing Sheets



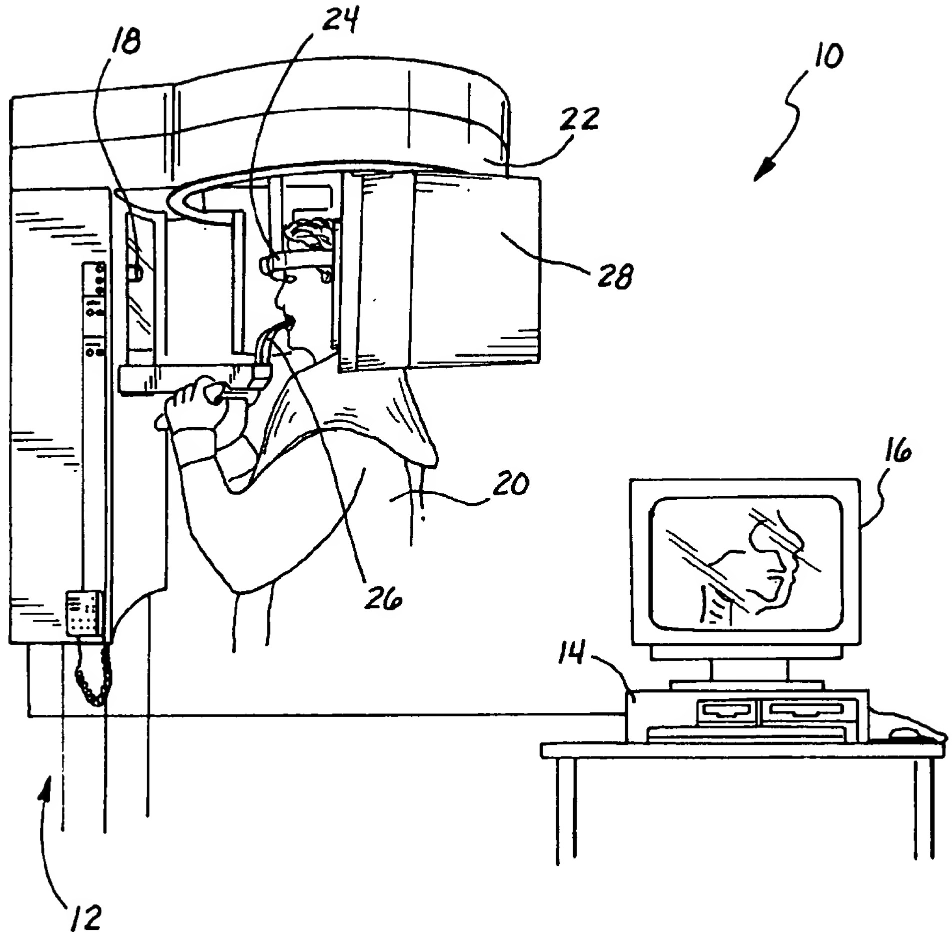


Fig. 1

Fig. 2

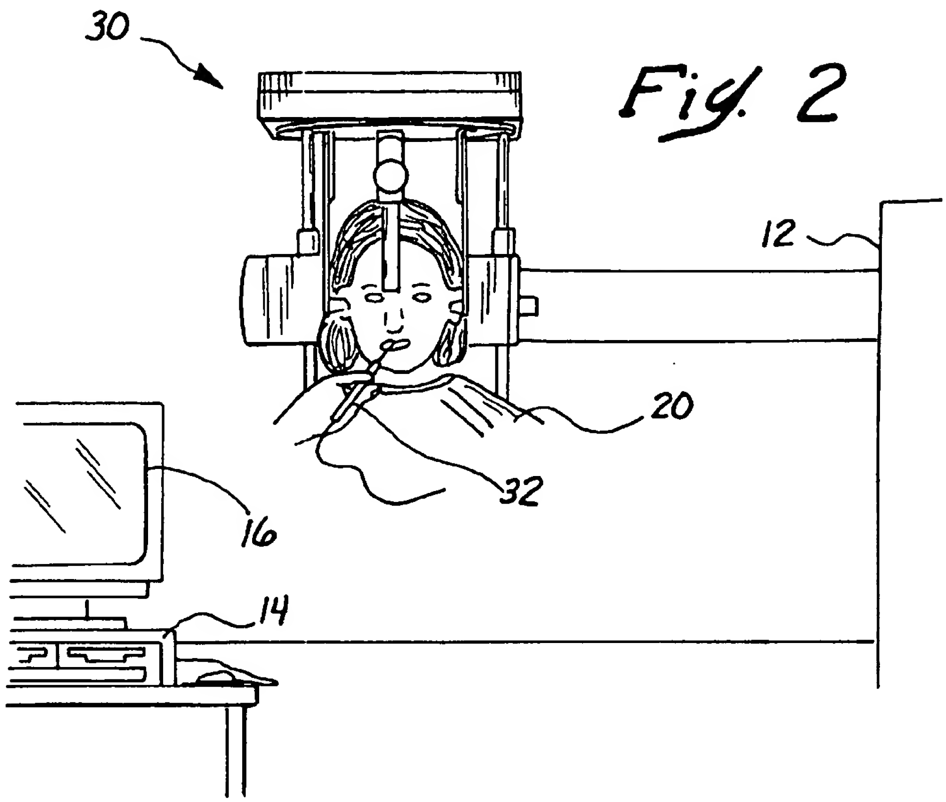

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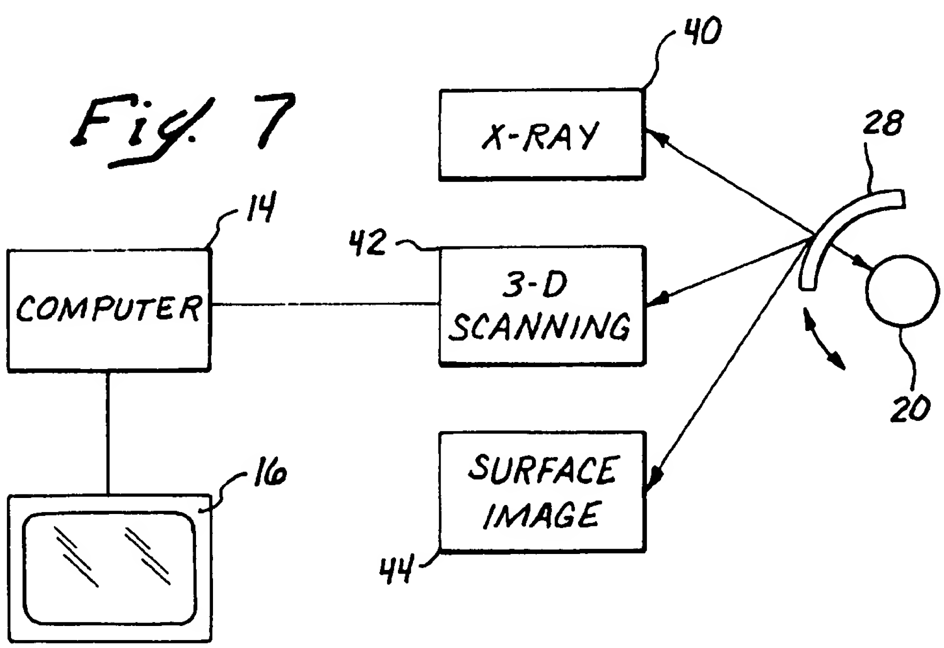
Fig. 7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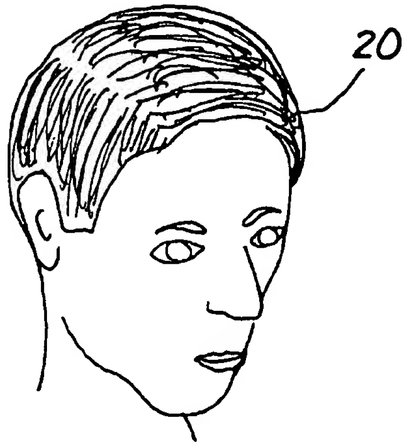
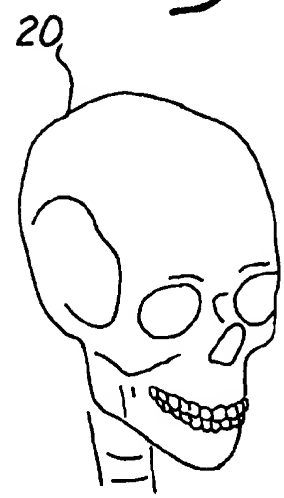


Fig. 3

Fig. 4



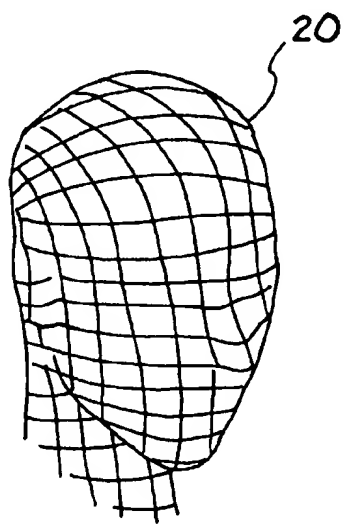
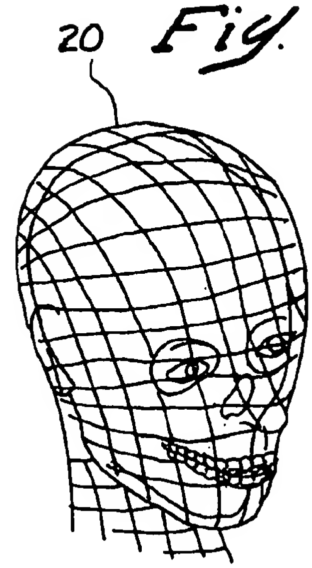


Fig. 5

Fig. 6



SCANNING DEVICE OR METHODOLOGY TO PRODUCE AN IMAGE INCORPORATING CORRELATED SUPERFICIAL, THREE DIMENSIONAL SURFACE AND X-RAY IMAGES AND MEASUREMENTS OF AN OBJECT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to the field of measurement and visualization of the superficial surface appearance, three dimensional contour and subsurface structure of an object, and in particular to improvements in orthodontics and oral surgery in measuring and visualizing anatomical landmarks used in orthodontic analysis by direct measurement of the face, head and jaws of a subject to produce correlated video, laser and x-ray derived measured images and to topologically transform the same to hypothetical modifications for visualization.

2. Description of the Prior Art

The apparatus for generating cephalometric tracings directly from a patient by generating digitized two or three dimensional data from a patient's head from defined locations of preselected landmarks is well known and is based on the use of optical or sonic marking using three dimensional triangulation. For example, such an apparatus is shown and described in Lemchen, et al. *"Method and Apparatus for Generating Cephalometric Images,"* U.S. Pat. No. 5,278,756 (1994) in which a means for defining a position with respect to a given anatomical reference is provided by a probe having a tip which generates signals of a certain optical or sonic frequency, when activated when positioned at selected reference points on the head or jaw. Triangulation detectors receive the position indicating signals from the probe and a computer processes the received signals to provide digital data corresponding to the three dimensional location of the probe tip with reference to the head or jaw. A visual image of the head or jaw is displayed as seen from a chosen direction or directions with a video camera. The video image is displayed together with a cephalometric tracing as would be seen in the same direction and scale which tracing is derived by joining appropriate anatomical landmarks with tracing lines generated by the computer according to any one of a number of accepted tracing techniques.

Lateral cephalograms using x-ray exposures are also well known from conventional orthodontic diagnosis. One prior art system for computer generating lateral cephalometric tracings is described in Ricketts, et al., *"Orthodontic Diagnosis and Planning"* as published by Rocky Mountain Orthodontics of Denver, Colo. (1982).

Panoramic radiography is also well established and has recently been commercialized to create digitized x-ray panographs as, for example, as provided by the system sold under the trademark, Siemens SIDEXIS, as manufactured by Pelton & Crane of Charlotte, N.C. Digitized x-ray signals are received directly from the panographic exposure and real time processing enables immediate display of the x-ray images on a monitor.

However, the panographic gantry and exposure equipment operates solely in connection with a single x-ray exposure and image. The laser optical or sonic equipment described in U.S. Pat. No. 5,278,756 also operates solely in relationship to a single detection and imaging system. The data from the separate x-ray panograph and the optical or sonic cephalometric trace can be downloaded into a single computer and through nontrivial and substantial computing effort with some degree of programming skill, the two sets of data can be correlated after the fact. However, such an approach requires multiple exposure apparatus, and considerable time and computer operator skill in order to obtain usefully correlated x-ray and laser images.

Marks, *"Combined Imaging Scanner,"* U.S. Pat. No. 5,391,877 (1995) describes an image scanner that combines images obtained from two systems that are supported on a combined gantry. The Single Photon Emission Computed Tomographic (SPECT) Scanner includes a gantry supporting a computed tomographic (CT) Scanner **12**. The gantry also supports the SPECT Scanner **14**. The single table **16** supporting the patient's position sequentially pass through both gantries. Initially the CT data is obtained and then the SPECT data. The single computer **18** mathematically convolves the two image data sets. The CT data is processed to provide a background or map on which to superimpose the SPECT data. As The CT anatomical data is convolved with the SPECT radioisotope distribution data to provide a color-shaded relief image. A single computer **18** is used for the analysis. The information is displayed on a machine control display **20**, a raw CT display terminal **22**, and a raw SPECT display terminal **24** and a combined CSPECT display terminal **26**. Image on the display terminal **26** can be printed to a color laser printer **28**.

Wessels, *"Alignment System to Overlay Abdominal Computer Aided Tomography and Magnetic Resonance Anatomy With Single Photon Emissions Tomography,"* U.S. Pat. No. 5,299,253 (1994) describes a system comprised of machine-base support means: (a) with a contrasting marker means (b) attached to the support for providing a set of markings which uniquely identifies a cross-section of an imaged object. The support means includes material encasement, and means to encapsulate the contrasting markers in an inert material. The material for the encasement may be polymer, wood, foam, metal, ceramic or a combination of these materials which do not otherwise interfere with the imaging system. Contrasting marker (b) is a mark whose outline can be accurately viewed without distortion or blurring within the image system being used. The marker can have many shapes including that of a solid or hollow tube. The contrast agent in the marker is a solid, liquid or gas which is readily discernible with a particular type of imaging system used. The pattern of contrast markers must be such that there is at least one transversely constant contrast marker and at least one transversely variable contrast marker spanning the longitudinal and imaging area. The alignment system can be used in one plane, or there can be a series of alignment systems in planes above the object to be imaged. In use, for registering single photon emission tomography images with computer tomography or magnetic resonance images, the object to be imaged placed on a support means. The support means can be a partial cast of the object's external shape. At least a portion of the object is adjacent to a contrast marker means. The object is imaged using two or more imaging techniques. At least two images of the object are registered to produce a coherent image of the object.

Mohr, et al., *"System and Method For Using A Dual Modality Detector For Inspecting Objects,"* U.S. Pat. No. 5,519,225 (1996) describes an industrial inspection system using a dual modality gas ionization detector with beams of either neutrons or photons from X-rays or gamma rays passing through the object. A dual modality gas ionization detector **10** has a window **16** for transmitting X-rays or gamma rays. The windows is made of a material which is permeable to these types of radiation. The detector includes

a housing **12** that has an ionization chamber **18** filled with high pressure gases such as helium or Xe, which chamber **18** is used to detect the neutron, x-ray or gamma rays fluxes incident on the ionization detector.

The inspection system is used to detect the presence of nitride and titanium sponge nuggets or residual core material in hollow-cast turbine engine blades. Mohr was cited for showing the simultaneous irradiation of objects with two types of radiation and the simultaneous and alternating detection of the same. The structure of the Mohr device includes a collimator **20** comprised of two bars **22** and **24** define a slit **26** between them which collimates the beams entering the chamber into a thinner beam. The beams entering the chamber interact with gases to produce a secondary-ionization charge that has accelerated toward electrodes **28**. A single layer of nuggets **34** on conveyor belt **40** are imaged by moving past a dual radiation source **42**, which alternately pulses neutrons and X-rays or gamma rays at the nuggets. The dual modality gas ionization detector **10** measures the transmissivity of the alternating radiation passing through the nuggets and supplies a signal to image generator **46**. Image generator **46** includes an analog digital converter **48**, processing means **50** and an image display device **52**.

Dumoulin, et al., "*Stereoscopic X-Ray Fluoroscopy System using Radiofrequency Fields,*" U.S. Pat. No. 5,251,635 (1993). The system is directed to minimizing an X-ray dose while still providing a stereoscopic tracking image of an invasive device in a patient. FIG. **1** shows a patient **112** positioned in the X-ray imaging system. The system provides a stereoscopic view of the patient with the X-ray image being only occasioned updated. The computer system tracks the invasive device and provides a superimposed image of the evasive device with the position being updated at a high rate. The invasive device has a transmitter coil that transmits an RF signal to a plurality receiving coils placed around the patient. The tracking computer calculates the position and orientation of the invasive device and supplies the image superpositioned on the last X-ray image. The tracking system can be used with other imaging systems such as magnetic resonant scanners, ultra sound scanners, positron emission, tomography scanners and the like.

Suckewer, et al., "*X-Ray Laser Microscope Apparatus,*" U.S. Pat. No. 4,979,203 (1990) describes an X-ray contact microscope and optical phase contrast microscopic system. Object cells **22** have been cultured on an X-ray resist surface **46**. An inverted microscope **26** using light source **34** is used to position the object cells for exposure to a soft X-ray beam **30** from an x-ray laser source **200**. An ultraviolet light source **66** is provided to monitor fluorescent effects of the object.

None of the prior art references show a multiple scanning exposure system for dental application in which the dental X-ray is separately created and combined with video and laser scanning of a patient's face or jaw structure.

None of the systems are concerned with combinations which would combine surface data, and in particular, facial surface data, with underlying bone structural data derived from X-ray scans. The correlation between underlying bony structure and outward superficial tissues is a correlation which is qualitatively and conceptually different than correlation or alignment between different scans of the same internal structure.

What is needed is some type of apparatus and methodology whereby multiple scanned cephalometric or dental images can be conveniently, economically and quickly combined for usefully correlated result.

BRIEF SUMMARY OF THE INVENTION

The invention is an apparatus for simultaneously providing multiple scans of measured data from a patient comprising a plurality of scanning devices for providing the multiple scans of measured data from the patient, and a scanning gantry in which the plurality of scanning devices are mounted at least in part for scanning the patient. A computer system or workstation correlates the output from each of the multiple scanning devices to provide at least a composite image of the patient attained therefrom in which the measure data of the multiple scans are correlated to each other.

In the illustrated embodiment the scanning gantry rotates at least in part about a portion of interest of the patient. The scanning gantry rotates about the lips, teeth and jaw structure of the patient.

The plurality of scanning devices includes an x-ray exposure device, such as a panoramic x-ray exposure device or a teleradiographic x-ray exposure device.

The plurality of scanning devices also includes a video imaging device, and preferably a color video imaging device.

The plurality of scanning devices still further includes a three dimensional scanning device.

In the preferred embodiment each of the plurality of scanning devices acquires data simultaneously and simultaneously stores the multiple data in the computer system as correlated data. It is also contemplated that the plurality of scanning devices acquire data in sequence doing a single exposure session of the patient and stores the sequentially acquired data as correlated within the computer system.

In particular, the plurality of scanning devices acquires tooth and jaw structure data in a first scanning device, three dimensional contour data through a second scanning device and superficial surface data through a third scanning device. The same scanning device may collect more than one of the data sets if desired. The tooth and jaw structure, three dimensional contour data and superficial surface data are correlated by the computer system to provide a composite image thereof.

The invention is also a method of creating correlated multiple scans of a patient to correlate bone structure to skin contour and to surface appearance comprising imaging a bone structure, skin surface contour and skin surface image of a patient by correlated multiple scans of the same. The skin surface image may be in color and the skin surface contour may use any type of three dimensional display representation desired such as mesh net images, contour lines or shading. The multiple scans of correlated data are simultaneously displayed to produce a composite image.

The invention having now been briefly summarized, can be better visualized by turning to the following drawings wherein like elements are referenced by like numerals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side perspective view of a digital dental topography panoramic device which includes x-ray scanning, laser or sonic cephalometric tracing and video imaging in a single real time mechanism.

FIG. **2** is a depiction of utilization of the device of FIG. **1** in which the anatomical landmarks are being optically or sonically marked.

FIG. **3** is a perspective depiction of a video image of the surface of a patient taken with the device of FIGS. **1** and **2**.

FIG. 4 is a panographic x-ray of the teeth and jaw bone of a patient taken in the device of FIGS. 1 and 2.

FIG. 5 is a laser contour of the anatomical landmarks of the patient taken in the device of FIGS. 1 and 2.

FIG. 6 is a superposition of the three scans depicted in FIGS. 3, 4 and 5 taken in real time in the device of FIGS. 1 and 2.

FIG. 7 is a block diagram of the invention which shows an X-ray exposure and detection system carried by gantry with a three dimensional contours scanning system and a surface image scanning system.

The invention and its various embodiments, now having been briefly summarized and visually depicted in the foregoing drawings, can be understood by turning to the following detailed description.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A conventional digital panoramic radiographic unit includes sonic or optical three dimensional scanning detector and a color video detector so that when the panoramic x-ray data is obtained, three dimensional contour of the surface of the patient's skin and the outward visual appearance of the patient's skin are also obtained as correlated data sets. The correlated data sets are then stored within a computer system as three sets of simultaneously or near simultaneously taken correlated data. The correlated data is then deconvolved to form a two-dimensional image of the tooth and jaw structure of patient as correlated to the patient's jaw and lip contours and visual appearance from a selected viewpoint. Additional scans may be added as correlated data sets, such as three-dimensional surface scans of the teeth for orthodontic purposes.

FIG. 1 is perspective side view of the apparatus, generally denoted by reference numeral 10, which is a device for providing panoramic dental digital tomography in a manner similar to digital radiology devices such as sold under the trademark, Siemens SIDEXIS, by Pelton and Crane of Charlotte, N.C. Apparatus 10 is comprised generally of a console 12 which includes a computer 14 to which is connected a monitor 16 and video camera 18. Console 12 also includes an x-ray source and control circuitry for the x-ray source (not shown) for the purpose of providing a controlled x-ray exposure of a patient 20 positioned within a panoramic gantry 22. The patient's head is maintained stationary at a fixed position by means of a head brace 24 and the jaw is maintained in a fixed partially part separation by means of a jaw bite fixture 26. A rotating detector 28 rotates about the patient's head to obtain a digitized real time x-ray topographic image of the patient's teeth and jawbone structure.

It must be clearly understood that the configuration of the device shown in FIG. 1 is only illustrative and is not limiting to the scope of the invention. Many other types and configurations of scanning systems could be employed, which are now known or may be later devised which would be equivalent to the SIDEXIS in one or more of its features. The feature of the system of FIGS. 1 and 2 which is relevant to the invention is that it is suitable for providing dental exposures of x-rays, three dimensional imaging or scanning and superficial images in a single gantry or scanning mechanism shared by all of the exposure and detection elements.

Device 10 can also be reconfigured to provide teleradiography by means which is conventional and thus will not be further discussed here. The point is that the scanning mechanism used in the invention may be of any type now known or later devised to create any desired dental or orthodontic images and is not just moving direction images like panoramic radiographs or fixed direction images like teleradiographs. The teleoradiographic unit 30 is depicted in the perspective view of FIG. 2. Different radiographic programs as well as immobilization fixtures can be utilized in the apparatus and methodology of the invention, again without limitation to what is illustrated here. For example, 16 different radiographic programs for diagnosis of the jaw region of patient 20 are conventionally included within the panoramic videographic apparatus 10 in the SIDEXIS system. However, it is expressly understood that the invention is not limited by the modalities of operation of panoramic radiographic devices currently available or as made later available, but includes within its scope any type of digitized x-ray diagnostic equipment.

At the same time that the panographic radiograph of patient 20 is being taken by apparatus 10, video camera 18 of apparatus 10 also is taking a real time corresponding or correlated video image of the patient's face and in particular, that portion of the head relating to the patient's lips and jaw structure or teeth. The video imaging system may be of the type shown in U.S. Pat. No. 5,278,756, which is incorporated herein by reference, or may be any type of imaging system now known or later devised which can provide a digitized or digitizable image of the surface of the patient's head, face, jaw and/or lips, and teeth.

In the preferred embodiment the three dimensional color scanning system of Cyberware of Monterey, Calif., is used to provide both the superficial color image of the face, jaw, lips and teeth, and the three dimensional contours of the face, jaw, lips and teeth. The dentist or oral surgeon is thus able to work with true human faces by obtaining images as little as 12 seconds. The Cyberware Model WB4 whole-body scanner allows capture of the shape and color of the entire human body. To capture the intricacies of the human body in one pass, the scanner uses one or more scanning instruments mounted in apparatus 10. A linear ball-bearing rail and servo motor assembly may be used to move the scanning instrument in the desired directions or the rotating gantry of the SIDEXIS may be employed. The use of multiple scanning instruments improves accuracy on the sides of the face or body and in difficult-to-reach areas. The WB4 scans a cylindrical volume 2 meters (79 inches) high with a diameter of 1.2 meters (47 inches). These dimensions accommodate the vast majority of human subjects. For even larger subjects, available zippering software enables two or more scans to be quickly combined into a complete three dimensional color model.

The scanner is controlled via Cyberware software running on a Silicon Graphics workstation. Cables connect each scanning instrument to a SCSI controller unit and a power supply unit. The SCSI controllers connect to the workstation, which automatically collects the measurements into a complete three dimensional model. Graphics tools allow the scanned model to be viewed within seconds after completing a scan.

The three dimensional color digitizer, such as Cyberware's Model 3030, scans an object at high resolution in less than a minute and shows the resulting three dimensional image on a graphics workstation with true-to-life color. The availability of color information to three dimensional digitizing provides nearly all the information a graphics application needs to fully describe an object. In addition to enhancing realism in graphic models, color denotes boundaries that are not obvious from shape alone. Color indicates surface texture and reflectance. By marking by any visible

means available an object's surface before digitizing, color can be used to transfer ideas from the object to the graphic model. In specialized applications, color can reveal characteristics such as skin discoloration.

The digitizer is entirely software controlled, and requires no user adjustments in normal use. In operation, the digitizer shines a safe, low-intensity laser on an object to create a lighted profile. A high-quality video sensor captures the profile from two viewpoints. The system can digitize thousands of these profiles in a few seconds to capture the shape of the entire object.

Simultaneously, a second video sensor acquires color information.

The scanning process captures an array of digitized points, with each point represented by x, y, and z coordinates for shape and 24-bit RGB coordinates for color. The digitizer transfers this data via SCSI to a graphics workstation for immediate viewing and modification.

The digitizer operates under the control of software running on a graphics workstation. The scanning process is thus automatic and easily adaptable to a variety of different requirements. Either rectangular or cylindrical scans can be performed depending on the shape of the object to be scanned. Multiple scans of a complex object can be combined into one model.

Software tools available from Cyberware allow manipulation and analysis of the three dimensional models in a variety of ways. Automatic measurement attributes such as area and volume can be obtained of selected portions of the three dimensional image. The models can be edited with operations such as clipping, scaling, and image cut and paste.

Popular third-party multimedia programs from Autodesk, Wavefront, and Alias, for example to work with the three dimensional models. Translation tools are available that convert the data array to a form readable by many third-party programs. Special-purpose translation routines may be custom created by the user. A feature extraction tool prepares three dimensional models for use in computer-aided design and other applications.

The scanner includes a completely self-contained optical digitizing head. It includes a low-intensity laser light source; quartz-coated, first-surface mirror assembly; high-quality imaging optics; 100% blemish-free, CCD (solid-state) video range and color sensors; and supporting electronics.

In an alternative embodiment after the x-ray, surface and contour images of the patient's head has been taken by the digitizer describe above, it is then possible to use a light or sonic handheld probe **32** such is described in connection with U.S. Pat. No. 5,278,756 to identify anatomical landmarks in the patient's jaw structure and/or face while the patient is still maintained in the exposure position as shown in FIG. 1 to include in a combined graphic model. Again, the specific means by which the anatomical tooth and jaw structure of the patient are determined through optical laser means need not be identical or even the same as discussed in connection with U.S. Pat. No. 5,278,756, but may include any type of three dimensional spatial orientation apparatus and methodology now known or later devised. In particular, patient landmarks may be made by the surgeon or orthodontics in the graphically displayed data itself by computer marking a point in the displayed image with a marker using a computer mouse or pen. The land-marked points can then be specifically used in later applied, conventional data reductions methodologies to compute tracings or to provide keystone points which will be moved or rotated according to expected orthodontics or oral surgery to provide a morphed image.

The object of the invention is that a real time visual or color video scan of the superficial facial and jaw structure of the patient is taken at the same time or at least at a time thereafter in which the patient is still in the same position and apparatus **10** has taken a panographic x-ray exposure and image. Three sets of data, one corresponding to the panographic x-ray, one corresponding to the facial color video image, and another corresponding to the optically identified anatomical landmarks are then established in the exposure space at or within the time of a single exposure session so that the data can be correlated before rendition of the display of each of the sets of data and preferably, but not necessarily, at the same time each set of data it is obtained through the use of a single mechanical scanning stage or mechanism.

For example, FIG. **3** diagrammatically illustrates patient **20** as would be seen in a color video image of the patient's face showing the superficial parents of the teeth, lips, chin and jaw structure as would be commonly be seen by an observer.

In FIG. **5**, the optically determined three dimensional physical contour of the patient's face, and in particular the lips, and selected anatomical landmark positions within the patient's jaw structure or teeth are established in three dimensional space. Any depiction of the topology of the patient's face may be employed such as a mesh-net representation or topological contour or elevation lines.

In FIG. **4** the panographic x-ray of the teeth and jaw structure of the patient in digitized form is depicted. These three images, which may be scanned simultaneously or at least within the same exposure session can then be point by point correlated or superimposed on each other in order to obtain a composite image such as shown in FIG. **6**. It should become readily apparent that the composite image allows the orthodontic surgeon to quickly and readily visualize the relationship between jaw and tooth structure on one hand and facial lip and jaw contours, landmarks and superficial visual appearance on the other. The format and resolution of each of the sets of data may be the same or different from each other and from the display of the set of data according to user convenience and choice.

Through three dimensional computer morphed techniques, using conventional software, it is then possible to move or change tooth or jaw structure positions and according to user selection. A corresponding three dimensional contours which have a scanned or measure relationship to the original x-ray data will be carried in the image with the x-ray data resulting in a morphed or altered composite display of FIG. **6**. The composite display can of course be deconvolved into any one of its constituent parts as shown in FIGS. **3**, **4** and **5** according to user selection as may be needed or desired for visualization.

FIG. **7** is a block diagram of the system **10** of the invention which shows an X-ray exposure and detection system **40** carried by gantry **28** with a three dimensional contours scanning system **42** and a surface image scanning system **44**. X-radiation, light, sonic energy is thus swept over patient **20** and the data simultaneously or near simultaneously provided in a correlated fashion to computer system **14** in which the three sets of data from systems **40**, **42** and **44** are stored in a correlated fashion. Thereafter, computer **14** may display the image of patient **20** by any one of scanning systems, **40**, **42** and **44** and further provide a composite image of each of these systems. Most importantly, data taken by one system is correlated to the data in another system as determined by the initial measure-

ment. Therefore, later when the operator through conventional computer graphing techniques morphs the data in any one set, the data in the other two sets can similarly be morphed in the same manner to obtain a correlated separate or composite image. In this way, surgical or orthodontic changes in the tooth or bone structure can be computer simulated and the contour and visual appearance of the patient's lips, teeth and jaw will be immediately correlated thereto and displayed in monitor **16**.

It must be expressly understood that more than or less than three data scanning systems may be employed to produce correlated data sets for orthodontic or oral surgery purposes, and there is no restriction under the invention as to what type of scanning mechanism or measurement signal might be employed.

Many alterations and modifications may be made by those having ordinary skill in the art without departing from the spirit and scope of the invention. Therefore, it must be understood that the illustrated embodiment has been set forth only for the purposes of example and that it should not be taken as limiting the invention as defined by the following claims.

It is to be expressly understood that the scanning, exposure, detection, computer, and software components of the invention which have been specifically described above are not to be read as limiting the invention, which is to include all known or later devised methods and apparatus for performing the same or similar functions in the dental and orthodontic fields.

The words used in this specification to describe the invention and its various embodiments are to be understood not only in the sense of their commonly defined meanings, but to include by special definition in this specification structure, material or acts beyond the scope of the commonly defined meanings. Thus if an element can be understood in the context of this specification as including more than one meaning, then its use in a claim must be understood as being generic to all possible meanings supported by the specification and by the word itself.

The definitions of the words or elements of the following claims are, therefore, defined in this specification to include not only the combination of elements which are literally set forth, but all equivalent structure, material or acts for performing substantially the same function in substantially the same way to obtain substantially the same result. In this sense it is therefore contemplated that an equivalent substitution of two or more elements may be made for any one of the elements in the claims below or that a single element may be substituted for two or more elements in a claim.

Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, now known or later devised, are expressly contemplated as being equivalently within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are defined to be within the scope of the defined elements.

The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptionally equivalent, what can be obviously substituted and also what essentially incorporates the essential idea of the invention.

I claim:

1. An apparatus for simultaneously providing multiple scans of measured data from a patient comprising:

a plurality of scanning devices for providing said multiple scans of measured data from said patient;

a scanning gantry in which said plurality of scanning devices are mounted at least in part for scanning said patient; and

a computer system for correlating output from each of said multiple scanning devices to provide at least a composite image of said patient attained therefrom in which said measure data of said multiple scans are correlated to each other,

wherein said plurality of scanning devices acquires subsurface structural data from said patient by at least a first scanning device and surface data from said patient by at least a second scanning device, said subsurface structure data and surface data from said patient being correlated by said computer system to provide a composite image of subsurface structural data and surface data of said patient.

2. An apparatus for simultaneously providing multiple scans of measured data from a patient comprising:

a plurality of scanning devices for providing said multiple scans of measured data from said patient;

a scanning gantry in which said plurality of scanning devices are mounted at least in part for scanning said patient; and

a computer system for correlating output from each of said multiple scanning devices to provide at least a composite image of said patient attained therefrom in which said measure data of said multiple scans are correlated to each other;

wherein said plurality of scanning devices acquires tooth and jaw structure data in a first scanning device, three dimensional contour data through a second scanning device and superficial surface data through a third scanning device, said tooth and jaw structure, three dimensional contour data and superficial surface data being correlated by said computer system to provide a composite image thereof.

3. The apparatus of claim **2** wherein said first scanning device of said plurality of scanning devices includes an x-ray exposure device.

4. The apparatus of claim **2** wherein said first scanning device of said plurality of scanning devices includes a panoramic x-ray exposure device.

5. The apparatus of claim **2** wherein said first scanning device of said plurality of scanning devices incorporates a teleradiographic x-ray exposure device.

6. The apparatus of claim **2** wherein said third scanning device of said plurality of scanning devices includes a video imaging device.

7. The apparatus of claim **2** wherein said second scanning device of said plurality of scanning devices includes a three dimensional scanning device.

8. The apparatus of claim **2** wherein each of said plurality of scanning devices acquires data simultaneously and simultaneously stores said multiple data in said computer system as correlated data.

9. The apparatus of claim **2** wherein said plurality of scanning devices acquires data in sequence doing a single exposure session of said patient and stores said sequentially acquired data as correlated within said computer system.

10. The apparatus of claim **2** wherein said data from said first, second and third scanning devices is taken simultaneously.

11. The apparatus of claim **2** wherein said data taken from said first, second and third scanning devices is taken with respect to one of said scanning devices sequentially during the same exposure session of said patient.

12. A method of creating correlated multiple scans of a patient to correlate bone structure to skin contour and to surface appearance comprising:

imaging a bone structure, skin surface contour and skin surface image of a patient by correlated multiple scans of the same; and

simultaneously displaying said multiple scans of correlated data to produce a composite image.

13. The method of claim 12 where said imaging occurs simultaneously with respect to each of said correlated scans.

14. The method of claim 12 wherein said imaging occurs at least in part sequentially with respect to said correlated scans at the same patient session.

15. The method of claim 12 wherein said imaging acquires panoramic x-ray data simultaneously with three dimensional contour of a patient's lips, teeth and jaw structure with simultaneous surface images of a patient's lip and jaw structure to produce said composite image.

* * * * *

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Weise et al. (43) Pub. Date: Jan. 30, 2003

(54) METHOD AND APPARATUS FOR REGISTERING A KNOWN DIGITAL OBJECT TO SCANNED 3-D MODEL

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(21) Appl. No.: 10/136,607

(22) Filed: May 1, 2002

Related U.S. Application Data

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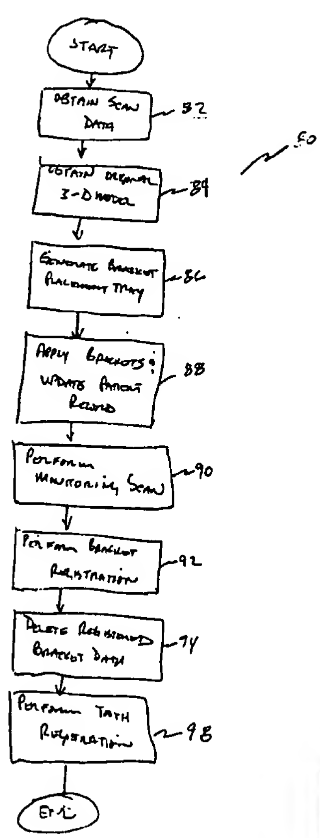
Publication Classification

(51) Int. Cl.[7] G06K 9/00

(52) U.S. Cl. 382/128; 382/154

(57) **ABSTRACT**

Method and apparatus for registering an object of known predetermined geometry to scanned three dimensional data such that the object's location may be verified. Such a known object may comprise a less than ideal three-dimensional (3-D) digital object such as a tooth, a dental appliance (e.g., as a tooth bracket model) or other like object, including portions thereof. Knowledge of such an object's location is generally helpful in planning orthodontic treatment, particularly where the location of the object needs to be determined or confirmed or where incomplete or poor scan data is obtained. Aspects of the present invention provide methods of effectively verifying dental appliance location and displaying appliance locations using a computer and three-dimensional models of teeth.



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(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2003/0169913 A1**

(43) **Pub. Date: Sep. 11, 2003**

Kopelman et al.

(54) **DENTAL IMAGE PROCESSING METHOD AND SYSTEM**

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(21) Appl. No.: **09/830,264**

(22) Filed: **Apr. 23, 2001**

Related U.S. Application Data

(63) Continuation of application No. PCT/IL99/00577, filed on Nov. 1, 1999.

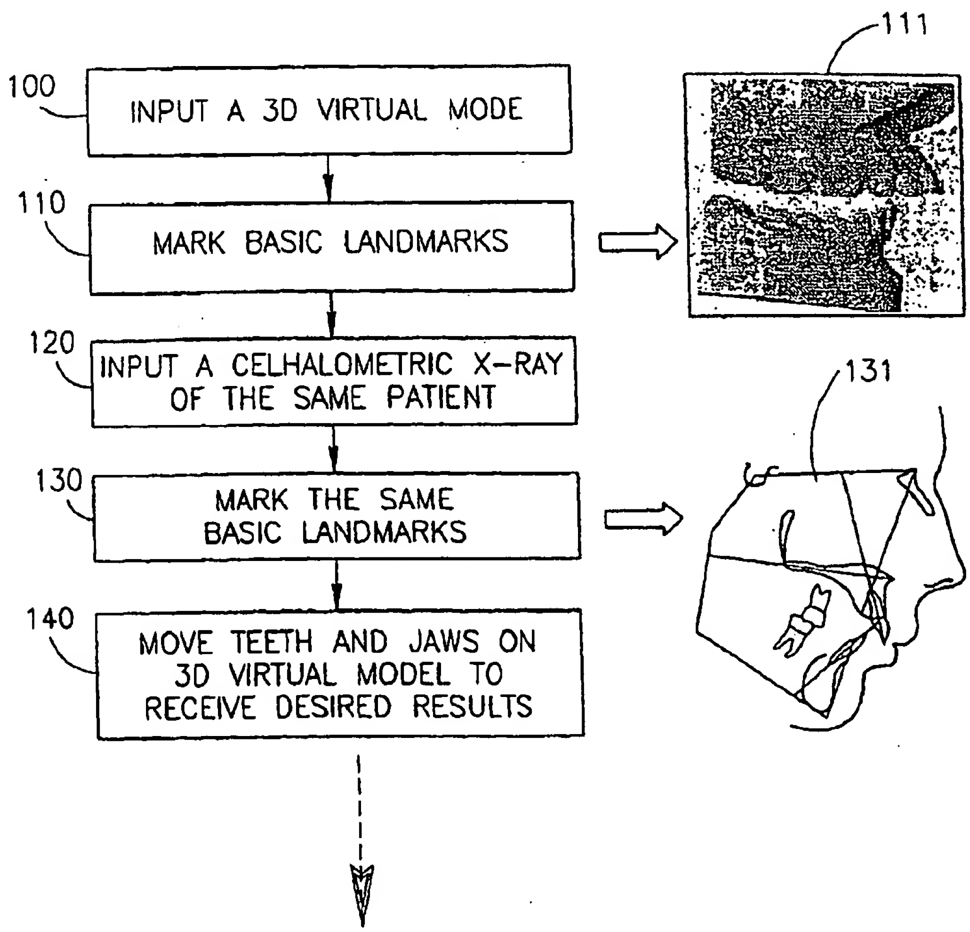
Publication Classification

(51) **Int. Cl.**^{7} **G06K 9/00**

(52) **U.S. Cl.** **382/132**; 382/154

(57) **ABSTRACT**

An image processing method for use in dentistry or orthodontic is provided. Two images of teeth one being a two-dimensional image and one a three-dimensional image are combined in a manner to allow the use of information obtained from one to the other. In order to combine the two images a set of basic landmarks is defined in one, identified in the other and then the two images are registered.



US 20020176612A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2002/0176612 A1**

Tuncay et al. (43) **Pub. Date: Nov. 28, 2002**

(54) **SYSTEM AND METHOD OF DIGITALLY MODELLING CRANIOFACIAL FEATURES FOR THE PURPOSES OF DIAGNOSIS AND TREATMENT PREDICTIONS**

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(22) Filed: **May 25, 2001**

Publication Classification

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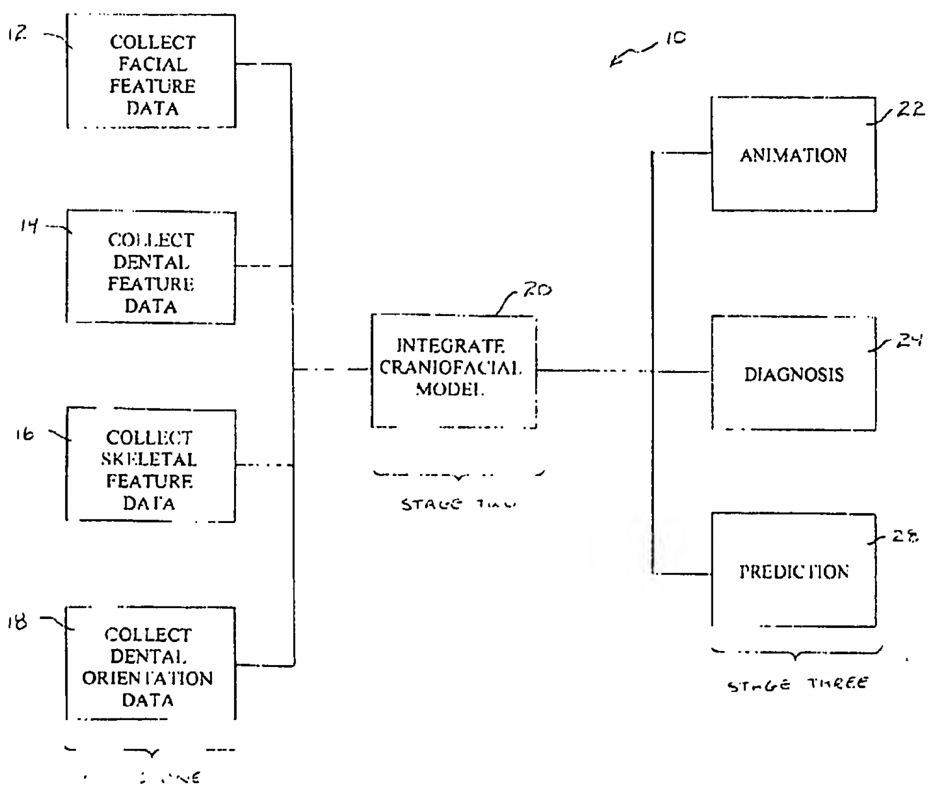
(52) **U.S. Cl.** **382/128**

(57) **ABSTRACT**

A system and method for generating and utilizing a computer model of the craniofacial features of a patient is claimed. To create the computer model, three-dimentional data regarding the patient's facial features, dental features and skeletal features is collected. Data regarding facial features is acquired using laser scanning and digital photograph. Data regarding dental features are acquired by physically modeling the teeth and laser scanning the models. Lastly, data regarding the skeletal features is obtained from radiographs. The data are combined into a single computer model that can be manipulated and viewed in the three-dimensions. The model also has the ability to be animated between the current modeled craniofacial features and theoretical craniofacial features.



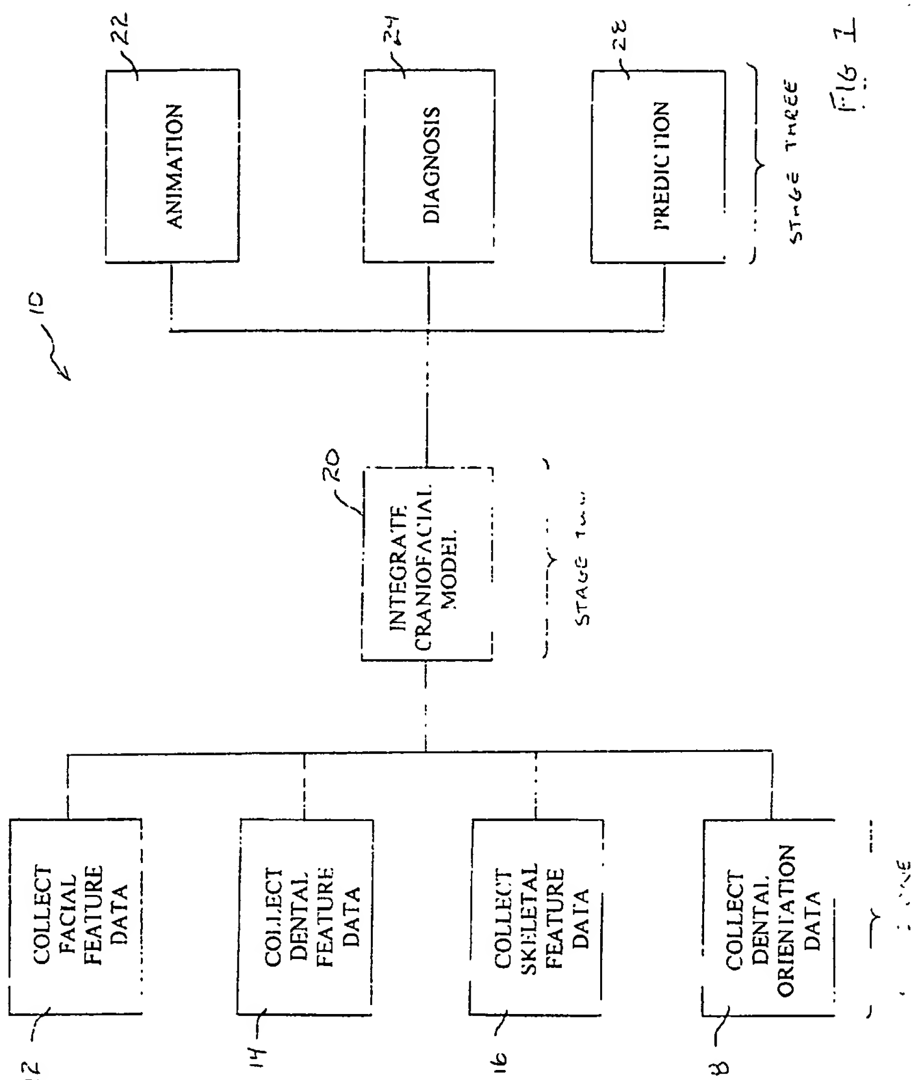

ANIMATION
DIAGNOSIS
PREDICTION
STAGE THREE
INTEGRATE CRANIOFACIAL MODEL
COLLECT FACIAL FEATURE DATA
COLLECT DENTAL FEATURE DATA
COLLECT SKELETAL FEATURE DATA
COLLECT DENTAL ORIENTATION DATA
10
12
14
16
18
20
22
24
28

FIG 1

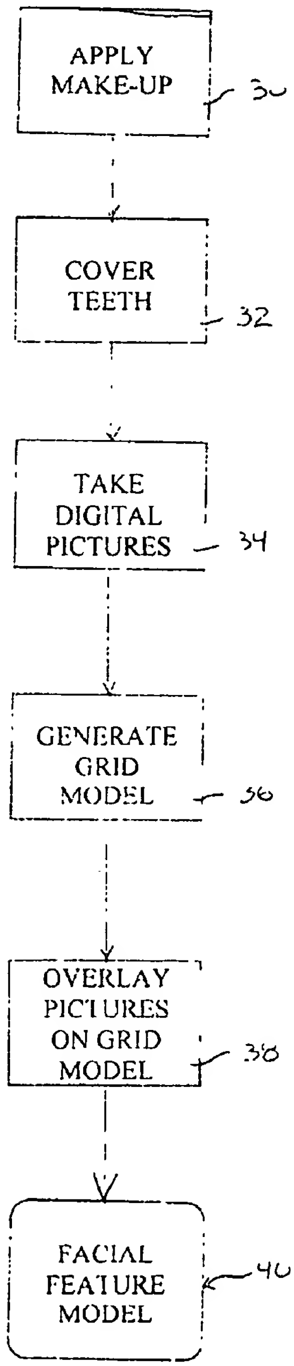

APPLY
MAKE-UP
30
COVER
TEETH
32
TAKE
DIGITAL
PICTURES
34
GENERATE
GRID
MODEL
36
OVERLAY
PICTURES
ON GRID
MODEL
38
FACIAL
FEATURE
MODEL
40

FIG 2

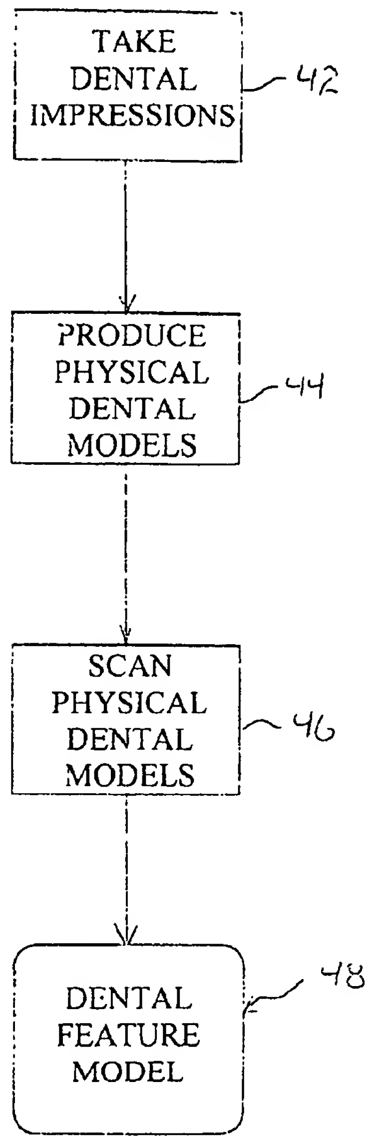

TAKE
DENTAL
IMPRESSIONS
42
PRODUCE
PHYSICAL
DENTAL
MODELS
44
SCAN
PHYSICAL
DENTAL
MODELS
46
DENTAL
FEATURE
MODEL
48

FIG. 3

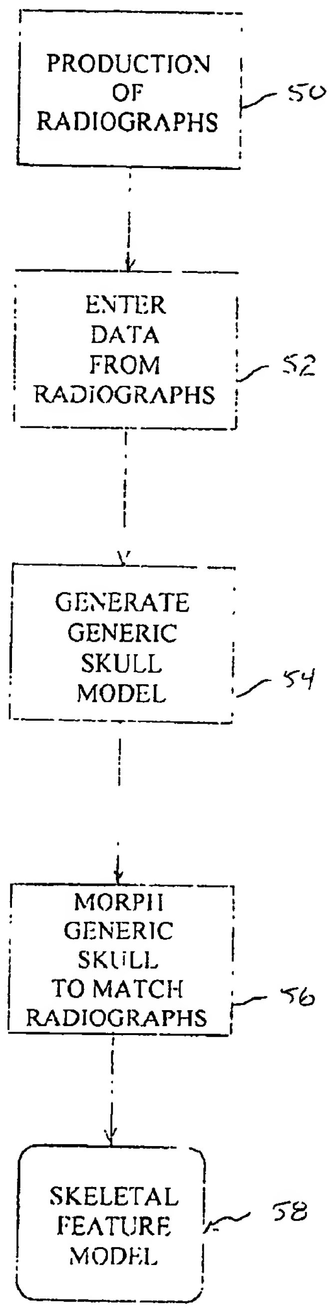
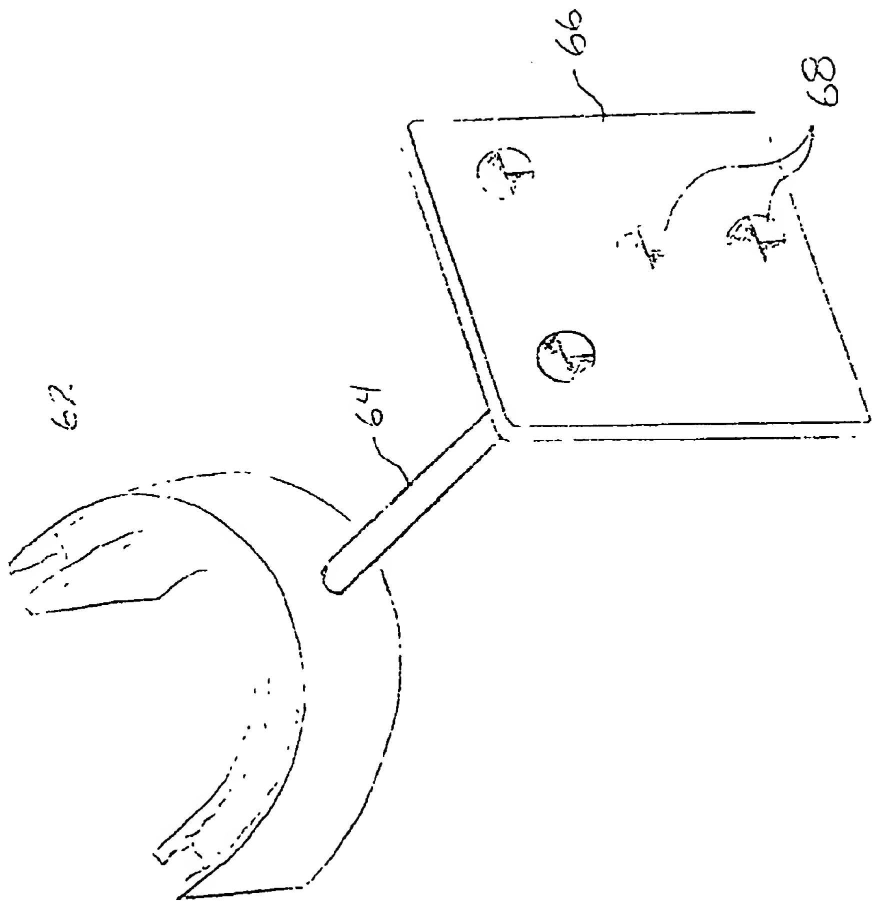

PRODUCTION
OF
RADIOGRAPHS
50
ENTER
DATA
FROM
RADIOGRAPHS
52
GENERATE
GENERIC
SKULL
MODEL
54
MORPH
GENERIC
SKULL
TO MATCH
RADIOGRAPHS
56
SKELETAL
FEATURE
MODEL
58

FIG 4

FIG. 5



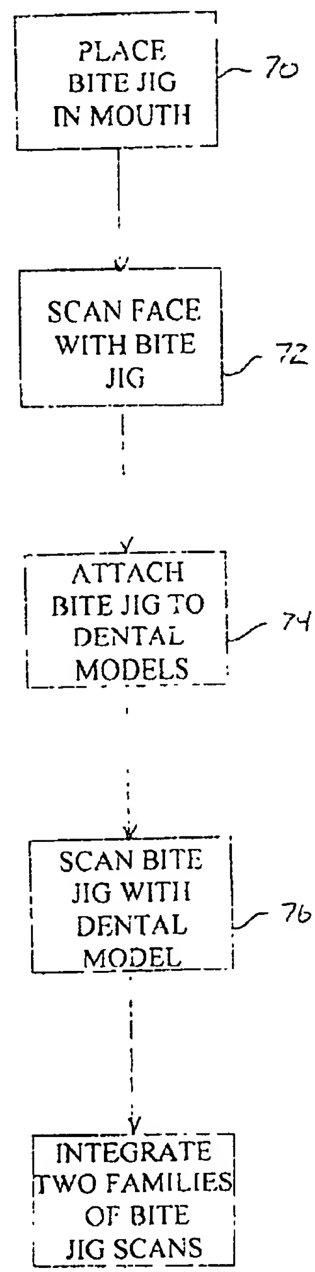

PLACE BITE JIG IN MOUTH
70
SCAN FACE WITH BITE JIG
72
ATTACH BITE JIG TO DENTAL MODELS
74
SCAN BITE JIG WITH DENTAL MODEL
76
INTEGRATE TWO FAMILIES OF BITE JIG SCANS

FIG 6

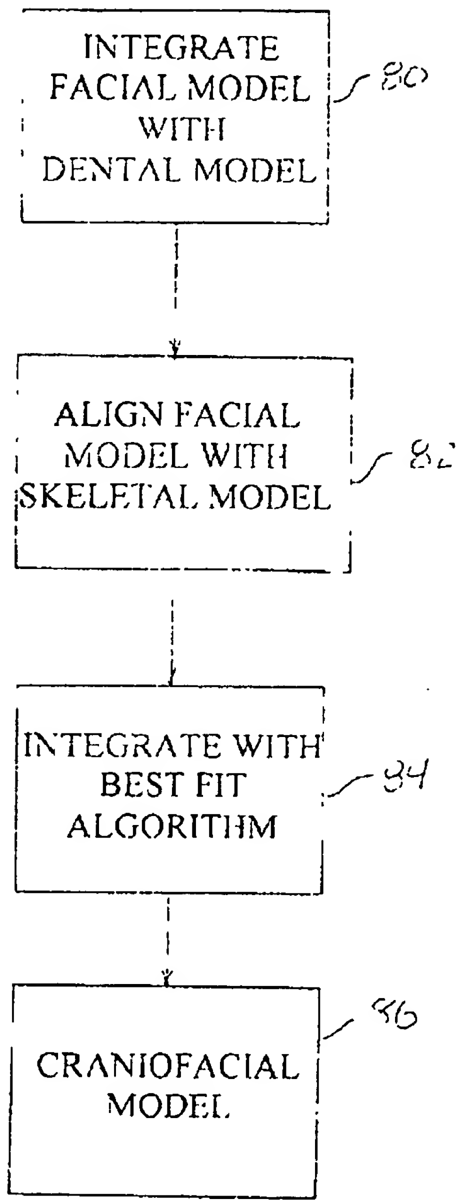

INTEGRATE FACIAL MODEL WITH DENTAL MODEL
80
ALIGN FACIAL MODEL WITH SKELETAL MODEL
82
INTEGRATE WITH BEST FIT ALGORITHM
84
CRANIOFACIAL MODEL
86

FIG 7

SYSTEM AND METHOD OF DIGITALLY MODELLING CRANIOFACIAL FEATURES FOR THE PURPOSES OF DIAGNOSIS AND TREATMENT PREDICTIONS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] In general, the present invention relates to systems and methods that are used to diagnose craniofacial deformities and predict outcomes to various treatments for those deformities. More particularly, the present invention relates to computer imaging and modeling systems that are used to create and manipulate craniofacial images.

[0003] 2. Description of the Prior Art

[0004] The craniofacial characteristics of each person are unique, thereby defining a person's appearance. However, due to genetics, some people are born with undesired craniofacial features or craniofacial deformities. Furthermore, in this dangerous world, many people incur injuries to there craniofacial features that must be treated.

[0005] The task of treating craniofacial trauma, correcting craniofacial deformities and altering undesired craniofacial features typically fall into the practice of orthodontists, oral surgeons and plastic surgeons, depending upon the type of corrective measures required.

[0006] When a surgeon or orthodontist alters the craniofacial features of a patient, the appearance of the patient may change. Both physicians and patients are very weary of this change. Often, the change to the craniofacial features can be anticipated. For example, when a patient has a few crooked teeth straightened, the physician and patient alike can easily visualize the patient's appearance. However, other procedures are not so easily visualized. If a patient is having jaw surgery, a rhinoplasty or other such procedure, both the physician and the patient want to visualize the change prior to undergoing the operation. The physician needs to visualize the anatomical change for the purposes of diagnosis. The patient wants to visualize the change because it is his/her appearance that is to be altered.

[0007] The prior art is replete with systems that help physicians and patients predict the changes that will occur in a patient's anatomy and appearance as a result of craniofacial surgery. Many such systems are currently commercially available and are sold under trade names, such as Quick Ceph, Dentofacial Planner, Orthovision, Dolphin Imaging and the like.

[0008] However, the craniofacial features of a person are three-dimensional. Most all the commercially available systems for imaging craniofacial features only provide two-dimensional images. As such, these prior art systems only enable physicians and patients to view changes in the profile view. Such predictions are useful but are not sufficient to truly visualize a changes that may occur after a craniofacial procedure. Some systems have been developed that attempt to provide imaging in three dimensions. Such systems are exemplified by U.S. Pat. No. 6,081,739 to Lemchen, entitled Scanning Device Or Methodology To Produce An Image Incorporating Correlated Superficial Three Dimensional Surface And X-Ray Images And Measurements Of An Object; U.S. Pat. No. 5,867,588 to Marquardt, entitled Method And Apparatus For Analyzing Facial Configurations And Components; and U.S. Pat. No. 5,659,625 to Marquardt, also entitled Method And Apparatus For Analyzing Facial Configurations And Components. A problem with such prior art three-dimensional systems is their inability to accurately map external facial appearance with both the skeletal structure of the patient and the dental structure of the patient in a single image.

[0009] A need therefore exists for an improved method and system for creating three-dimensional models of a patient, that accurately includes external facial features, skeletal features and dental features, wherein that model can be virtually altered for diagnostic and treatment outcome purposes. This need is met by the present invention as described and claimed below.

SUMMARY OF THE INVENTION

[0010] The present invention is a system and method for generating and utilizing a computer model of the craniofacial features of a patient. To create the computer model, three-dimentional data regarding the patient's facial features, dental features and skeletal features is collected. Data regarding facial features is acquired using laser scanning and digital photographs. Data regarding dental features are acquired by physically modeling the teeth and laser scanning the models. Lastly, data regarding the skeletal features is obtained from radiographs. The data is combined into a single computer model that can be manipulated and viewed in the three-dimensions. The model also has the ability to be animated between the current modeled craniofacial features and theoretical craniofacial features. In this manner, the computer model can be used to diagnose abnormalities, and approximate physiological changes that may occur because of corrective surgery, braces, aging and/or growth.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a better understanding of the present invention, reference is made to the following description of an exemplary embodiment thereof, considered in conjunction with the accompanying drawings, in which:

[0012] **FIG. 1** is a block diagram schematic of the overall modeling system and method in accordance with the present invention;

[0013] **FIG. 2** is a block diagram schematic illustrating the method steps used to collect facial feature data;

[0014] **FIG. 3** is a block diagram schematic illustrating the method steps used to collect dental feature data;

[0015] **FIG. 4** is a block diagram schematic illustrating the method steps used to collect skeletal feature data;

[0016] **FIG. 5** is a perspective view of an exemplary embodiment of a bite jig;

[0017] **FIG. 6** is a block diagram schematic illustrating the method steps used to collect dental feature orientation data using the bite jig of **FIG. 5**; and

[0018] **FIG. 7** is a block diagram schematic illustrating the method step used in integrating the craniofacial model from the collected data.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The present invention is a system and method for generating a digital representation of the craniofacial fea-

tures of a patient, wherein the digital representation includes exact skeletal features, dental features and soft tissue facial features. The digital representation can then be altered and/or animated. By having the ability to alter and/or animate the digital representation, a process is created that is highly useful in diagnosing craniofacial problems and visualizing physical changes that can be created by various types of treatments.

[0020] Referring to **FIG. 1**, it can be seen that the present invention system and method **10** contains three stages. The first stage is the data collection stage. During the data collection stage, data of a patient's craniofacial features is collected. As is indicated by Block **12**, facial feature data is collected that is representative of the external appearance of the soft tissue components of a patient's face. As is indicated by Block **14**, dental feature data is collected that is representative of the condition and orientation of that patient's teeth. As is indicated by Block **16**, data is also collected on the skeletal features of the patient. Lastly, as is indicated by Block **18**, orientation data is collected that is used to orient the dental feature data in the overall craniofacial model. The steps used to collect the various types of data are unique and will later be explained in more detail.

[0021] Once all the data is collected, the second stage of the system and method **10** is implemented. As is indicated by Block **20**, the collected data from stage one is manipulated to create an accurate digital craniofacial model of the patient. As will be later explained, the craniofacial model models a patient's craniofacial features in three dimensions that can be viewed from any vantage point. The manipulation of the collected data in stage two is done in a computer through the use of novel software applications, as will also be later explained

[0022] The third stage of the system and method **10** is the use of the craniofacial model by a physician or patient. As is indicated by Block **22**, the craniofacial model can be animated to illustrate features through a variety of changing expressions. The craniofacial model can also be used to diagnose craniofacial abnormalities, as is indicated by Block **24**. The animation of the craniofacial model is very useful in diagnosing abnormalities that manifest themselves when a patient chews, smiles, yawns or otherwise undergoes movement in the craniofacial structure. Furthermore, as is indicated by Block **28**, the craniofacial model can be used to predict changes to the craniofacial features created by aging, growth, surgery or orthodontic appliances.

[0023] Each of the logic blocks illustrated in **FIG. 1** can be multiple process steps. Each of the logic blocks shown in **FIG. 1**, will therefore be individually described, beginning with the data collection blocks in stage one.

[0024] Referring to **FIG. 2**, the method of collecting facial data is more specifically described. To collect facial data, low gloss make-up is applied to the face of a patient. See Block **30**. The low gloss make-up is desired in order to accurately scan the facial features with a laser scanner. If make-up were not used, shinny points on the skin may distort the scanned image being collected. Furthermore, as is indicated by Block **32**, the teeth are covered. The teeth are skinny and reflect laser light. So to prevent distortions in a laser scan, the teeth are covered with a non-reflective material. Orientation points are then marked in the make-up at predetermined points.

[0025] Prior to laser scanning the patient's facial features, the patient's face is photographed using a digital camera. This is shown by Block **34**. Several pictures may be taken, wherein different pictures are taken at known distances and at known angles relative the primary plane of the patients face. Digital pictures may also be taken of different facial expressions, such as a smile, a grin, an mouth open and the like.

[0026] After the digital pictures have been taken, the patient's face is then scanned with a non-contact laser scanner. An example of an appropriate non-contact laser scanner would be the Vivid 700 model laser scanner produced by Minolta. The patient's face is scanned from the same positions and with the same expressions as were the digital picture. In this manner, a laser scan can be associated with a digital picture.

[0027] Using the data collected from each laser scan, a model grid framework of the patient's face is generated using commercial software. This is indicated by Block **36** in **FIG. 2**. For example, if a Vivid 700 laser scanner is used, Vivid 1.3 software can be used to create a model grid framework of the collected data. The orientation points placed on the patient's face are noted on the grid framework. The digital picture corresponding to each laser scan also contains the same orientation points, as does each laser scan. Using the orientation points as references, the digital picture for each laser scan is overlaid over the model grid framework that was generated for that scan. This process is indicated by Block **38** in **FIG. 2**. This provides facial texture to the collected data. Once the overlays are complete, a first digital model **40** is produced that corresponds to the facial characteristics of a patient. The facial feature model **40** is three-dimensional and contains data points from different perspectives and with different facial expressions.

[0028] Referring to **FIG. 3**, the steps involved in collecting dental feature data are described. To collect dental feature data on a patient, impressions are taken of the patient's teeth using conventional techniques. Block **42** in **FIG. 3** shows this process. Three-dimensional physical models of the teeth are then made from the impressions, as is indicated by Block **44**. Orientation points are placed on the physical models. Once the physical models are complete, the models are scanned using a non-contact laser scanner. Block **46** indicates this process. A computer model **48** of the patient's dental features is therefore created that represents the patient's actual dental features in three dimensions.

[0029] Referring to **FIG. 4**, the steps involved in collecting skeletal data are described. To collect skeletal data, lateral and PA radiographs are taken of the skull using traditional radiology techniques. This process is shown by Block **50** in **FIG. 4**. Data points from the radiographs are then read into a computer, as is indicated by Block **52**. Furthermore, as is indicated by Block **54**, a generic three-dimensional skull is generated in the computer using commercial software. The data points from the radiographs are then projected around the generic skull. Using commercial software, such as 3D Studio Max, the generic skull computer model can be morphed to match the data points collected from the radiographs. This process is shown by Block **56** in **FIG. 4**. The result is a computer model **58** of a skull that mimics the actual skull of the patient.

[0030] Referring to **FIG. 5**, a bite jig **60** is shown that is used in the process of collecting dental orientation data. The

bite jig **60** has a bite plate **62** that engages the teeth within the mouth. A shaft **64** extends away from the bite plate **62**. The shaft **64** terminates with an orientation plate **66** that has reference points **68** on it.

[0031] Referring to **FIG. 6**, the method of collecting dental orientation data with the bite jig **60** (**FIG. 5**) is described. As is indicated by Block **70**, the bite jig is placed in the mouth of the patient and is engaged by the patient's teeth. Once in place, the patient's face is again scanned using the non-contact laser scanner, as is indicated by Block **72**. The laser scans, therefore, collect data reference points from the patient's face as well as reference points from the orientation plate **66** (**FIG. 5**) on the bite jig.

[0032] As is indicated by Block **74**, the bite jig is then affixed to the physical models of the teeth that have been previously prepared. Once the bite jig is affixed to the models of the teeth, the entire assembly is scanned with the non-contact laser scanner. Block **76** indicates this process. As has been previously mentioned, the physical models of the teeth contain reference points that are detected in the laser scan. The orientation plate **66** (**FIG. 5**) on the bite jig also contains reference points that are detected by the laser scan. By scanning the model of the teeth engaging the bite jig, the orientation of the bite plate relative to the teeth becomes known.

[0033] Returning to **FIG. 1**, it will now be understood that from stage one of the process, three-dimensional models of the facial features, dental features, and skeletal features become known. See Blocks **12**, **14** and **16**. Furthermore, the positional relationship between the facial features and the orientation plate of the bite jig are known, as is the positional relationship between the orientation plate of the bite jig and the modeled teeth. See Block **18**.

[0034] Once this data is collected, stage two begins wherein the collected data is integrated into a single craniofacial model. The integration of the various data models can be done in a number of different ways. Referring to **FIG. 7**, it can be seen that since the positional relationship of the bite jig's orientation plate **66** (**FIG. 5**) is known relative to both the facial features and the dental features, the dental features can be oriented with the facial features by simply aligning common points on the orientation plate. The model of the facial features and the model of the dental features therefore integrate into a single model in a simple fashion. This initial integration is shown by Block **80** in **FIG. 7**. To integrate the skeletal features into the combined facial feature/dental model, the profile of the facial features is aligned over the profile of the modeled skull, as indicated by Block **82**. A front view of the facial features is then aligned with a front view of the modeled skull. The alignment is done along the mid-sagittal plane. Once proper alignment is achieved, the skeletal feature model and the facial feature model are integrated using commercially available best-fit algorithms, as is indicated by Block **84**.

[0035] The result after integration is a single craniofacial model **86** that contains detailed data about a patient's facial features, skeletal features and dental features. The craniofacial model **86** is three-dimensional, thereby producing a three-dimensional digital representation of a patient's craniofacial features.

[0036] Now that a three-dimentional representation of a patient's craniofacial structure has been developed, stage three (**FIG. 1**) can be started. In stage three, it can be seen that the craniofacial model can be used as a tool for medical diagnosis. See block **24** in **FIG. 1**. Using just a static three-dimentional model, a physician can visualize the asymmetry of dental arches from a coronal perspective. Jaw deformities, nasal deformities and eye socket deformities can also readily be visualized from the model. Furthermore, deformities in the soft tissue of the face can also be visualized.

[0037] To assist in diagnosis, the craniofacial model can also be animated, as is indicated by Block **22** in **FIG. 1**. To animate the model, many types of commercial animation software can be used, provided that software supports digital multi-frame animation. Examples of appropriate software packages are 3D Studio Max and Softimage. As has been previously mentioned, the facial features of the patient are scanned in a plurality of different poses. Using animation algorithms, any existing pose can be animated to morph into any other pose. As such, the model can be animated to smile, frown, chew or undergo any desired craniofacial movement.

[0038] The last way to manipulate the craniofacial model is to create artificial conditions and morph the craniofacial model to those artificial conditions. For example, a surgeon can create a false nose that illustrates what a patient's nose will look like after a surgical procedure. The craniofacial model can then be morphed into a condition that contains the false nose. As such, the patient can be shown before and after models of how their face will look after being effected by surgery. Furthermore, by morphing the craniofacial model into an anticipated future state, a physician can more accurately diagnose the effectiveness of different types of treatment on a patient's problems.

[0039] In addition to physical changes caused by surgery or braces, other physiological changes can also be illustrated. For instance, the model of a patient's face can be aged. If the patient is an adult, the age progression will show the onset of wrinkles and a loss of elasticity in the skin. If the patient is a juvenile, the age progression will show growth and maturity of the craniofacial features. In order to change the existing craniofacial model into any theoretical appearance, a final likeliness of that appearance must be added to the database of the model. The craniofacial model can then be easily morphed into that theoretical appearance. The creation of the theoretical appearance can be done by the physician or can be done by a computer artist who is knowledgeable in craniofacial physiology. The use of the model to predict physiological changes is shown by Block **28** in **FIG. 1**.

[0040] It will be understood that the embodiment of the present invention system and method described and illustrated herein are merely exemplary and a person skilled in the art can make many variations to the embodiments shown without departing from the scope of the present invention. All such variations, modifications and alternate embodiments are intended to be included within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A method of creating a digital computer model of the craniofacial features of a person, comprising the steps of:

creating a first computer model of the person's facial features;

producing a physical model of the person's teeth;

creating a second computer model of said physical model of said teeth; and

integrating said first computer model and said second computer model into a master computer model.

2. The method according to claim 1, further including the step of creating a third computer model of the person's skull.

3. The method according to claim 2, further including the step of integrating said third computer model into said master computer model.

4. The method according to claim 1, wherein said step of creating a first computer model includes the sub step of scanning the person's face in a plurality of poses with a laser scanner.

5. The method according to claim 4, wherein said step of creating a first computer model includes taking a plurality of digital photographs of the person's face.

6. The method according to claim 5, further including the sub step of combining data from said scans and said digital photographs.

7. The method according to claim 1, wherein said step of creating a second computer includes the sub step of scanning said physical model of said teeth with a laser scanner.

8. The method according to claim 1, further including the step of creating a bite jig having an orientation plate that extends outside the mouth.

9. The method according to claim 8, further including the steps of:

scanning the patient's head while biting the bite jig to create a first collection of data points;

coupling said physical model of said teeth to said bite jig in a subassembly; and

scanning said subassembly to create a second collection of data points.

10. The method according to claim 9 wherein said step of integrating said first computer model and said second computer model includes orienting said first computer model with said second computer model using said first collection of data points and said second collection of data.

11. The method according to claim 2, wherein said step of creating a third computer model, includes the sub steps of:

generating a generic skull model;

inputting data corresponding to the skull of the person;

altering the generic skull model to correspond to the data corresponding to the skull of the person.

12. A method, comprising the steps of:

creating a three-dimentional computer model of a person's craniofacial features, that includes skeletal features, dental features and facial features;

animating said computer model.

13. The method according to claim 12, wherein said step of creating a three-dimentional computer model includes the sub steps of:

creating a first computer model of the person's facial features;

producing a physical model of the person's teeth;

creating a second computer model of said physical model of said teeth; and

integrating said first computer model and said second computer model into a master computer model.

14. The method according to claim 12, wherein said step of animating said computer model includes creating a theoretical appearance of craniofacial features and animating said computer model between modeled craniofacial features and said theoretical appearance.

15. The method according to claim 14, wherein said step of animating said computer model includes animating said computer model to mimic actions selected from a group consisting of chewing, grinning, smiling, growing and aging.

16. The method according to claim 14, further including the step of creating a third computer model of the person's skull.

17. The method according to claim 16, further including the step of integrating said third computer model into said master computer model.

18. The method according to claim 14, wherein said step of creating a first computer model includes the sub step of scanning the person's face in a plurality of poses with a laser scanner.

19. The method according to claim 18, wherein said step of creating a first computer model includes taking a plurality of digital photographs of the persons' face.

20. The method according to claim 19, further including the sub step of combining data from said scans and said digital photographs.

* * * * *

US005318441A

United States Patent [19]

Keller

[11] Patent Number: 5,318,441

[45] Date of Patent: Jun. 7, 1994

[54] METHOD OF CEPHALOMETRIC EVALUATION OF DENTAL RADIOGRAPHS

[76] Inventor: Duane C. Keller, 62 Grantwood, St. Louis, Mo. 63123

[21] Appl. No.: 945,869

[22] Filed: Sep. 17, 1992

[51] Int. Cl.[5] A61C 3/00

[52] U.S. Cl. 433/68; 433/24; 433/72; 364/413.13

[58] Field of Search 433/68, 24, 72, 215; 364/413, 414, 415; 128/777, 749; 378/162, 163, 164, 205

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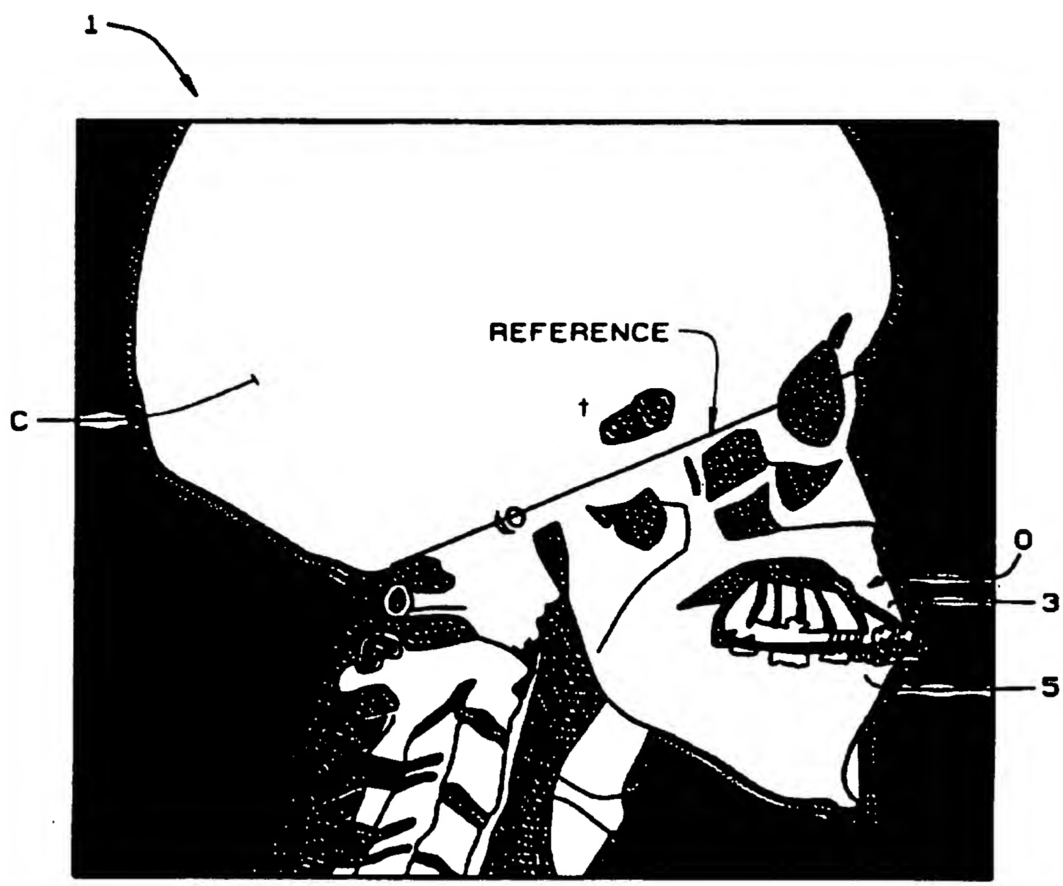
Primary Examiner—John J. Wilson
Attorney, Agent, or Firm—Polster, Lieder, Woodruff & Lucchesi

[57] ABSTRACT

A method for cephalometric evaluation includes steps of generating radiographic, X-ray or other image of a patient's individual orthodontic structure, positioning this image in alignment with a graphical depiction of a norm value orthodontic structure, and comparing the individual's structure to the norm value structure to analyze development and to determine a course of orthodontic or other treatment.

8 Claims, 3 Drawing Sheets



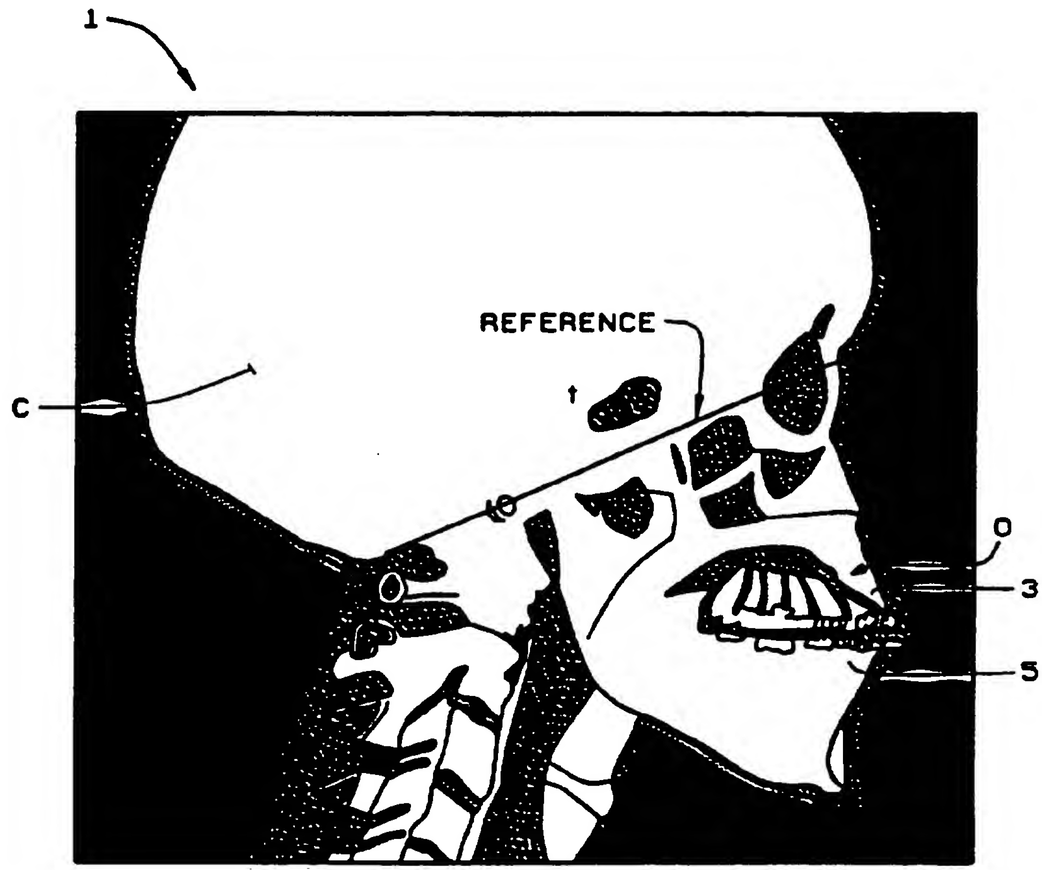


FIG. 1

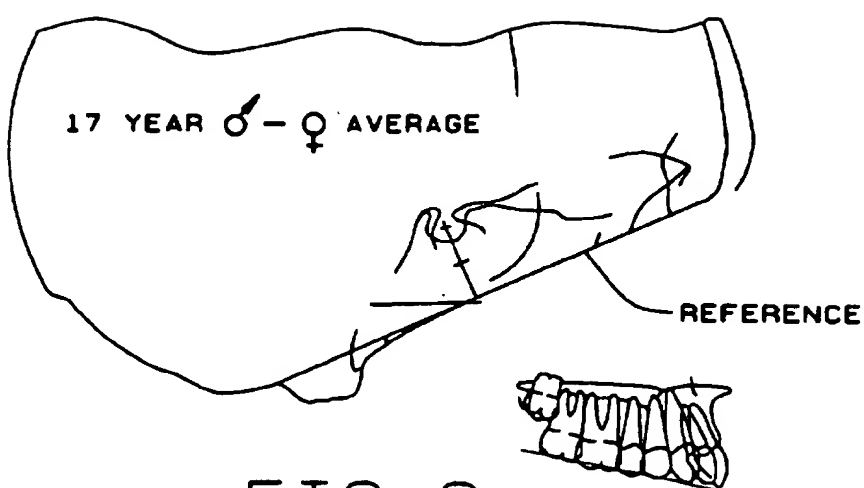


FIG. 2

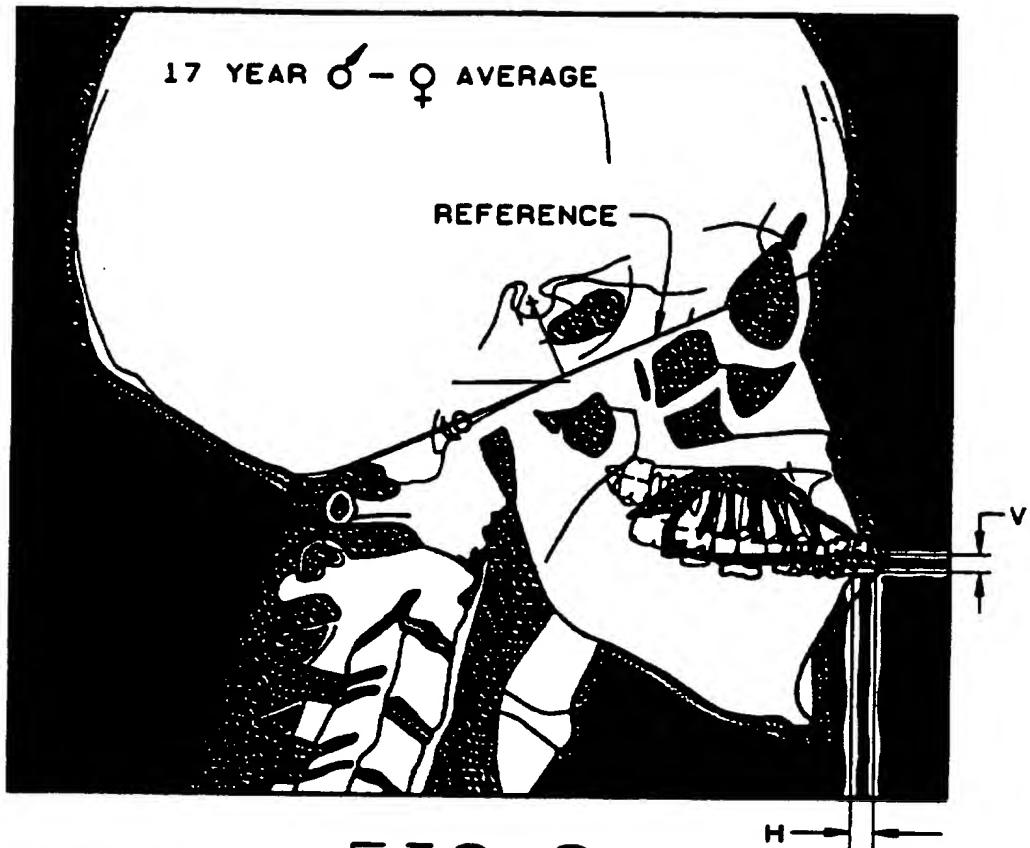


FIG. 3

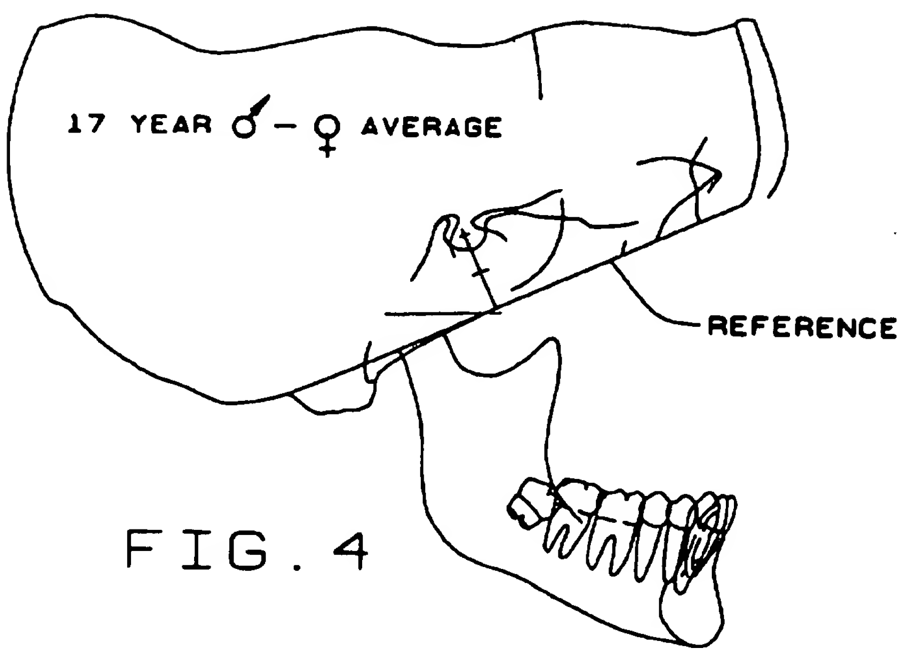


FIG. 4

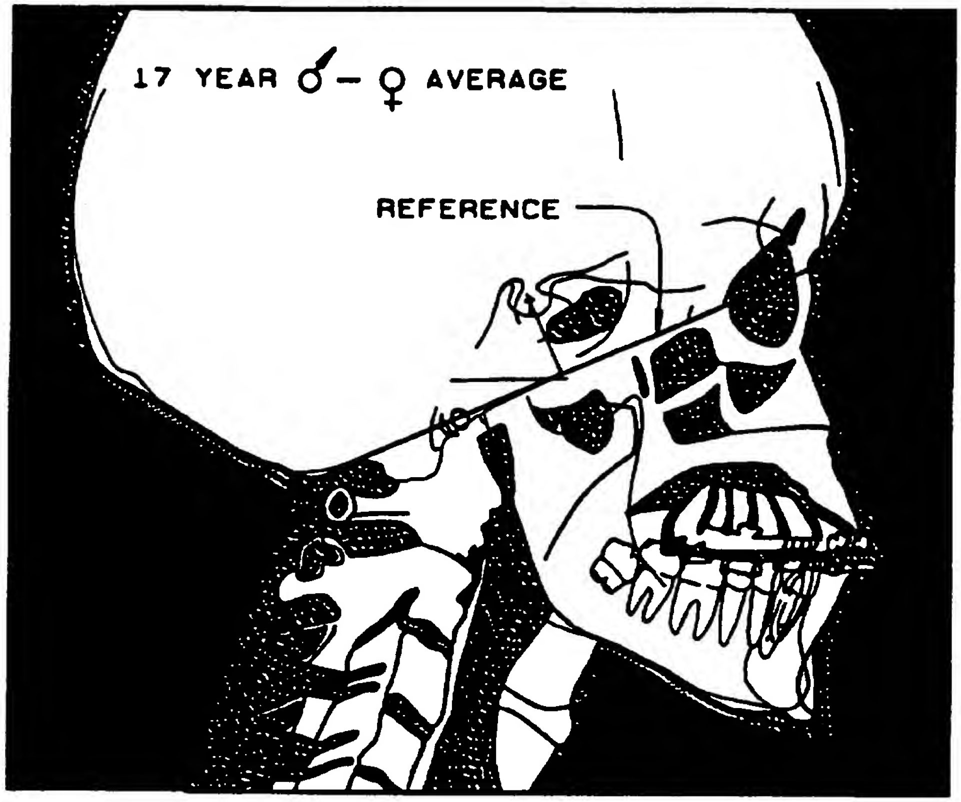


FIG. 5

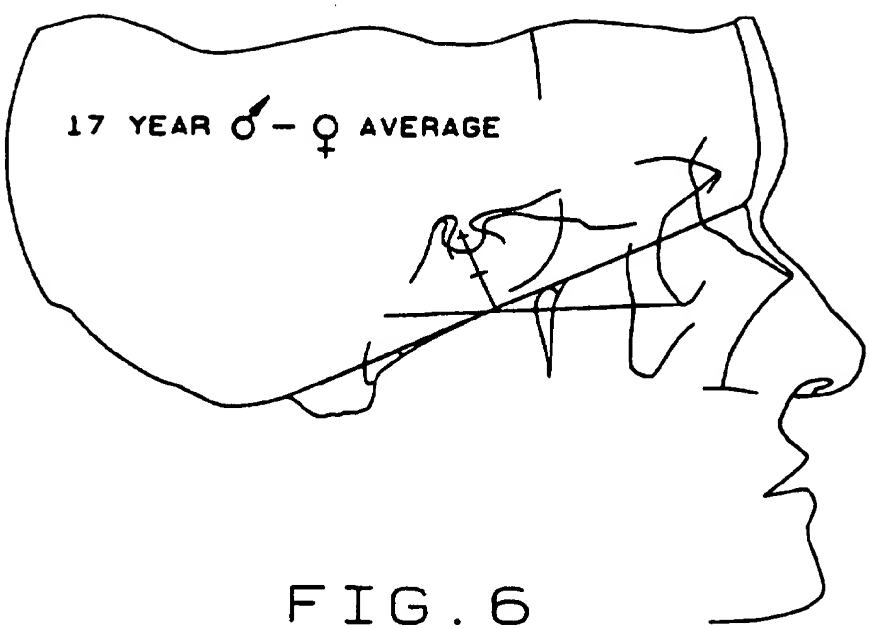


FIG. 6

METHOD OF CEPHALOMETRIC EVALUATION OF DENTAL RADIOGRAPHS

BACKGROUND OF THE INVENTION

This present invention relates to an improved method for cephalometric evaluation and more particularly to a method of analysis through comparison of depictions of structures in orthodontic patients to a normal value orthodontic and/or cranial structure for like patients of similar age or development.

The standard method for cephalometric evaluation of orthodontic patients is to take a radiograph (X-ray) and to plot specific points of interest. By plotting lines, angles and linear measurements, the practitioner is able to evaluate growth and development of an individual patient's orthodontic structures. These lines, angles and linear measurements are compared to other average or "norm" values of lines, angles and linear measurements as a base standard. The practitioner is required to carefully and, as accurately as possible, to plot out each point line and angle and measure each of these individually. Almost all methods of cephalometric analysis use the same specific points of interest for measurement. The practitioner focuses on points which yield the most helpful and consistent results for determining relative growth and development in orthodontic structures.

The measurements obtained from cephalometric analysis allow the practitioner to compare individual patients to average or norm patients of similar ages and ethnic backgrounds. One function of cephalometric analysis is to allow the practitioner to compare dental relations of a patient to individuals who exhibit normative occlusion. Another function is to compare skeletal relations of a patient's skeletal anteroposterior components to skeletal norms of similar individuals. The measurements also enable the practitioner to relate soft tissue outlines of a patient's face to ethnically similar individuals with normative occlusion. All of these functions enable the practitioner to establish the direction of growth and development in an individual's orthodontic structures. Once the direction of growth and development is established the practitioner can determine whether any orthodontic procedures are necessary to obtain a "normal" relationship. In addition, the measurements are helpful in determining whether an individual patient is at risk for certain types of temporomandibular joint (TMJ)dysfunction and if the patient already has TMJ dysfunction, the measurements help determine the desired steps for treatment.

Although the standard method of cephalometric analysis yields the desired results, there are several disadvantages which practitioners have struggled with for years. Manually plotting the specific points of interest and measuring the resulting lines and angles is extremely tedious and time consuming. The ability to obtain optimal precision is limited by the potential for human error in obtaining the measurements. The standard method is also subject to obvious radiographic distortion in areas where two overlapping structures are superimposed.

Various other features of the present invention will become obvious to one skilled in the art upon reading the disclosure set forth herein.

SUMMARY OF THE INVENTION

One of the objects of the present invention is to provide a method of cephalometric analysis that eliminates the need for plotting and measuring specific points, lines and angles.

Another object is to provide such a method which increases the accuracy of cephalometric analysis by decreasing the possibility of errors due to drafting mistakes or other mistakes likely t occur using the standard method of analysis.

Another object is to provide such a method which is quicker, easier and more cost effective than the standard method.

Another object is to provide such a method which allows the practitioner to compare an individual patient's orthodontic structures to a two dimensional norm orthodontic structure.

Another object is to provide such a method which allows the practitioner to compare orthodontic structures by region instead of being limited to specific points of interest.

Another object is to provide such a method which allows the practitioner to compare each region independently or to another selected region, or to a base (skull) reference.

Another object is to provide such a method which clearly depicts where the structures would be and where they actually are in relation to norm orthodontic structures.

Other objects of this invention will be apparent to those skilled in the art in light of the following descriptions and accompanying drawings.

In accordance with this invention, generally stated, an image of a patient's individual orthodontic structure is generated, as by taking a radiograph (X-ray). Using an image saves time and money compared to using linear measurements. The image is also not subject to potential drafting mistakes. In addition, the image provides a dramatic method for analysis since the practitioner is able to see an image of the structure itself instead of numbers representing the structure. The method further comprises positioning the individual orthodontic structure image in alignment with a graphical depiction (either a transparent depiction or a graphical display of such a picture on a computer display or the like) of an average or norm value orthodontic structure for a patient of similar age and ethnic background. And then a further step of comparing the image to the graphical depiction. This method of comparison is quicker and easier than the rigorous plotting and measuring involved in the standard method.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an image (a lateral radiograph), of a patient's orthodontic and cranial structure;

FIG. 2 is a graphical depiction, preferably on a transparent background or as displayed on a computer visual display, of a norm value orthodontic and/or cranial structure for a standard reference of similar race, age and/or degree of development showing a selected orthodontic structure (e.g., the upper teeth);

FIG. 3 shows the graphical depiction of the norm value orthodontics structure for the cranium and upper teeth of FIG. 2 overlayed on the patient's radiograph of FIG. 1 thus graphically showing deviations of the patient's upper teeth orthodontic structure (as shown on the radiographic image) to that of the norm value reference shown in FIG. 2; and

FIG. 4 is a view similar to FIG. 2 of a norm value rthodontic and/or cranial structure for a standard reference showing the lower teeth;

FIG. 5 is an overlay of the norm value orthodontic structure shown in FIG. 3 overlayed on the patient's image of FIG. 1 showing deviations of the patient's lower teeth orthodontic structure to that of the norm value.

FIG. 6 is a norm value reference of the soft tissue structure including the nose and lips and other soft tissue structure which may be overlayed with FIG. 1 (not shown) to graphically show the normal value location of such soft tissue to the actual location of the patient's soft tissue.

Corresponding reference characters represent corresponding parts throughout the various drawing figures.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawing figures, and more particularly to FIG. 1, a lateral radiographic (or X-ray) image, as generally indicated at 1, is shown for a particular patient. The radiographic or X-ray image is shown in side elevation and it depicts various structural features of the cranium C and of the patient's upper orthodontic structure 3 and the lower orthodontic structure 5. It will be understood that frontal images can be used with this method as well as lateral images.

In accordance with this method, the practitioner then establishes a reference line (or plane) R on the radiographic image 1 (as shown in FIG. 1). Reference line R is established by drawing a line on the radiographic image 1 from the bridge of the nasion to the lower base of the skull near the juncture of the mastoid process and the lowest portion occipital when viewed laterally. This line of reference extends through the eye socket and can, for example extend through the pterygomaxiallary fissure which is located interiorally of the zygomatic process.

Further in accordance with this method of cephalometric analysis, the practitioner selects a graphical depiction, as shown in FIGS. 2 or 4, of an average or norm value orthodontic structure for a patient of similar age and ethnic background to serve as a reference. For example, if the actual patient who's radiograph is illustrated in FIG. 1 is an average 17 year old male or female, then the graphical depiction for an average 17 year old of similar and ethnic background would be selected. However, it has been found that in accordance with this method if the actual radiograph for a patient is compared to his or her norm value orthodontic structure of similar age and ethnic background and if there is a general state of underdevelopment, then the norm value structure of a different age reference is utilized. It is then assumed that all other cranial and orthodontic structure of the patient are in proportion to the reference.

Further in accordance with the method of this invention, the selected norm value orthodontic structure, as shown in FIGS. 2 or 4, are on a transparent background which may be laid over the radiograph image shown in FIG. 1. The reference line R established on the radiograph is brought into register with a similar reference line or plane on the norm value orthodontic structure to form the overlay graphical depiction, as shown in FIGS. 3 or 5.

More specifically, the overlaid image shown in FIG. 3 shows a transparency with the norm value orthodontic structure of FIG. 2 properly positioned on the radiographic image 1 with the reference lines R on the image and on the reference on the norm value orthodontic depiction being in register with one another. The resulting overlay image shown in FIG. 3 then illustrates the relationship of, for example, the upper teeth reference (on the n rm value orthodontic structure) as shown in FIG. 2 in relation to the corresponding patient's upper teeth as shown in FIG. 1.

As shown in FIG. 3, the overlay illustrates vertical and horizontal deviations V and H of the patient's upper teeth relative to the upper teeth of the norm value orthodontic reference structure shown on the transparent overlay (FIG. 2). This readily shows the practitioner where the patient's orthodontic structures are in relation to norm orthodontic structures and also illustrates the amount of orthodontic correction required. It will be further appreciated that this method allows the practitioner to compare orthodontic structures by a particular region (e.g., the patient's upper teeth) instead of being limited to specific points of interest as were common in prior cephalometric analysis methods.

In a like manner, the norm value orthodontic structure for the patient's lower jaw, as is illustrated in FIG. 4 may be overlaid with the patient's radiograph of FIG. 1 so as to illustrate the position of the patient's lower teeth with respect to the norm value of the lower teeth of such orthodontic structure for a patient of similar ethnic background. Again, deviation of the patient's lower teeth to the norm value position and location of a known standard may be determined as was in the case of FIG. 3 so as to determine the direction and the amount of orthodontic correction required.

FIG. 6 illustrates a norm value reference for the facial soft tissue features of the patient in relation to the cranial and orthodontic structures illustrated in the norm value overlays shown in FIGS. 2 and 4. It will be appreciated that following a course of orthodontic treatment that, within a limited degree, the position of the patient's lips and chin may be modified to obtain a desired result.

In use, the method of the present invention involves first generating an image, preferably a radiographic image as shown in FIG. 1 of an individual's orthodontic structures, including the upper and lower teeth. Then, in the manner explained above, a norm value standard orthodontic structure is selected for the patient having a similar age and ethnic background, or being of a similar stage of development. Then, the individual orthodontic structural image is shown on the radiograph of FIG. 1 is positioned in alignment with the graphical depiction of the norm value orthodontic structure as shown on the transparency of FIG. 2 or 4. Then, the individual patient's orthodontic structural image, has shown on the radiograph of FIG. 1 may be compared to the norm value orthodontic structure of FIGS. 2 or 4 whereby the practitioner may evaluate development of the individual orthodontic structures and determine the course of treatment, the amount and direction of orthodontic treatment required.

The above method using the transparent overlay references of FIGS. 2 and 4 is preferred. However, it will be appreciated that the patient's radiographic image may be graphically displayed on a computer screen and the overlay reference may be combined with the patient's image on the computer screen rather than physically overlaying a transparent reference over the patient's X-ray.

It will be understood that over an extended course of orthodontic treatment, other radiographic images similar to FIG. 1 may be taken and compared to the norm value orthodontic structure so as to monit r the treatment and to make adjustments to the orthodontic structure.

Inasmuch as numerous changes or modifications may be made to the preferred embodiment of the invention as described in detail hereinabove without departing from the spirit and scope of the invention, it is therefore specifically noted that the scope of the invention is to be determined solely by the language of the following claims.

I claim:

1. Method of evaluating the relationship of individual orthodontic structures for a patient using a graphical depiction of a norm value orthodontic structure for said patient, said method comprising the steps of:
   a. generating a radiographic image of said individual orthodontic structures for said patient;
   b. positioning said individual orthodontic structure radiographic image in alignment with said graphical depiction of said norm value orthodontic structures for said patient; and
   c. graphically comparing said individual orthodontic structure radiographic image with said graphical depiction of said norm value orthodontic structure to evaluate development of said individual orthodontic structures.

2. A method of claim 1 further comprising selecting said norm value orthodontic structure by determining a cranial base reference for said patient.

3. The method of claim 2 wherein said step of selecting said n rm value rthodontic structure comprises the nasion, the base of the skull, and pterygomaxillary fissure, or ther selected reference points.

4. The method of claim 1 wherein said step f generating said image of said individual rthodontic structure comprises taking a radiographic image of the midface and upper teeth.

5. The method of claim 1 wherein said step of generating said image of said individual orthodontic structure comprises taking a radiographic image of the midface and upper teeth together with the sinuses, teeth, and related structures.

6. The method of claim 1 wherein said step of generating said image of said individual orthodontic structure comprises taking a radiographic image of the lower jaw and lower teeth.

7. The method of claims 4, 5, or 6 wherein said step of generating said image of said individual orthodontic structure further comprises taking a radiographic image of the surrounding soft tissue structure of the patient including the nose, lips, chin or other related soft tissue structure.

8. The method of claim 1 further comprising repeating the steps of claim 1 periodically throughout a course of treatment for the patient, monitoring the growth and development of said individual orthodontic structures of said patient over time, and graphically comparing the actual growth of said individual orthodontic structures to said image of said norm value orthodontic structure with said image serving as a reference.

* * * * *

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United States Patent [19]

Snow

[11] **Patent Number: 6,068,482**

[45] **Date of Patent: May 30, 2000**

[54] **METHOD FOR CREATION AND UTILIZATION OF INDIVIDUALIZED 3-DIMENSIONAL TEETH MODELS**

[76] Inventor: **Michael Desmond Snow**, 39 Balcombe Rd., Mentone Victoria 3194, Australia

[21] Appl. No.: **09/233,685**

[22] Filed: **Jan. 19, 1999**

Related U.S. Application Data

[63] Continuation of application No. 08/785,664, Jan. 17, 1997, abandoned.

[51] **Int. Cl.**[7] **A61C 5/10**

[52] **U.S. Cl.** **433/223**; 433/215; 433/24

[58] **Field of Search** 433/2, 8, 24, 223, 433/229

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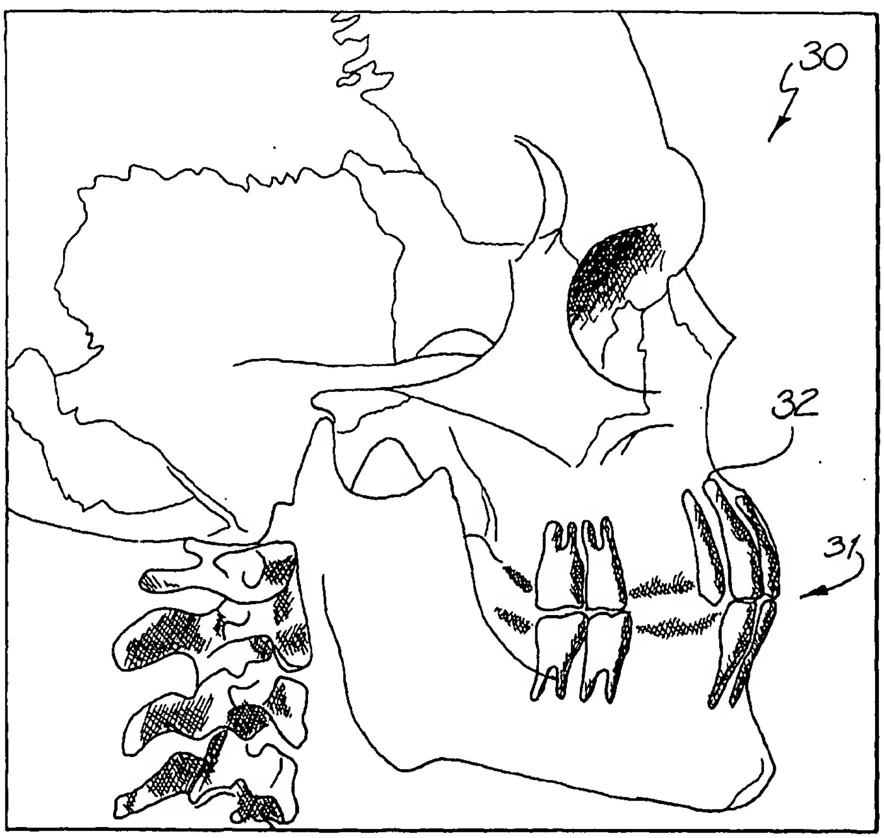
Primary Examiner—Nicholas D. Lucchesi
Attorney, Agent, or Firm—Townsend Townsend & Crew LLP; Jim F. Hann, Esq.

[57] **ABSTRACT**

A computerized dental record method includes imaging a patient's teeth as a two-dimensional image, visually superimposing an initial three-dimensional computerized tooth model onto the two-dimensional image of the patient's teeth, interactively adjusting the three-dimensional teeth so that they are aligned with the two-dimensional image, and then storing the adjusted computer graphic model of the teeth as the dental record.

6 Claims, 4 Drawing Sheets



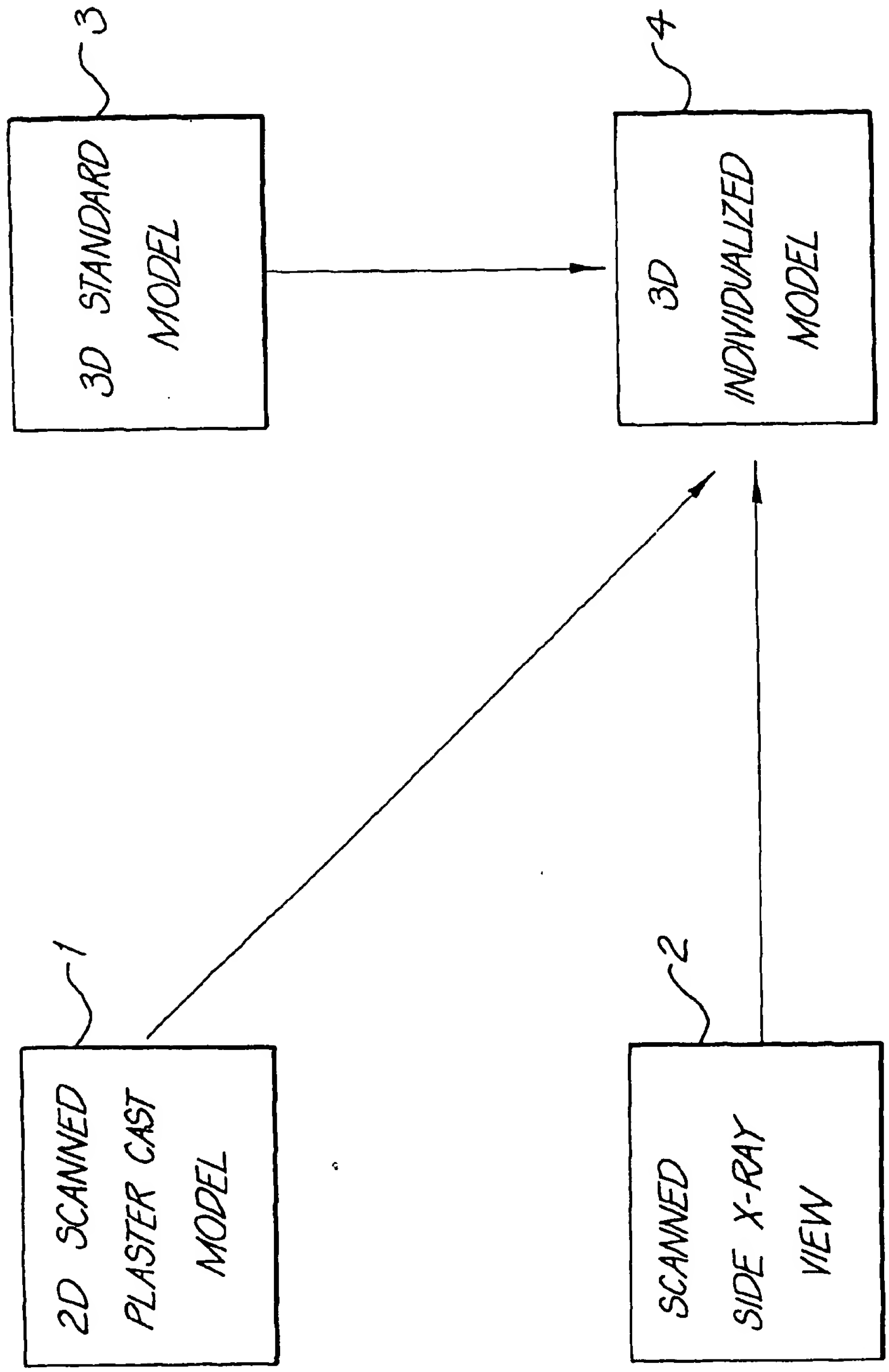

3
3D STANDARD MODEL
4
3D INDIVIDUALIZED MODEL
1
2D SCANNED PLASTER CAST MODEL
2
SCANNED SIDE X-RAY VIEW

FIG. 1

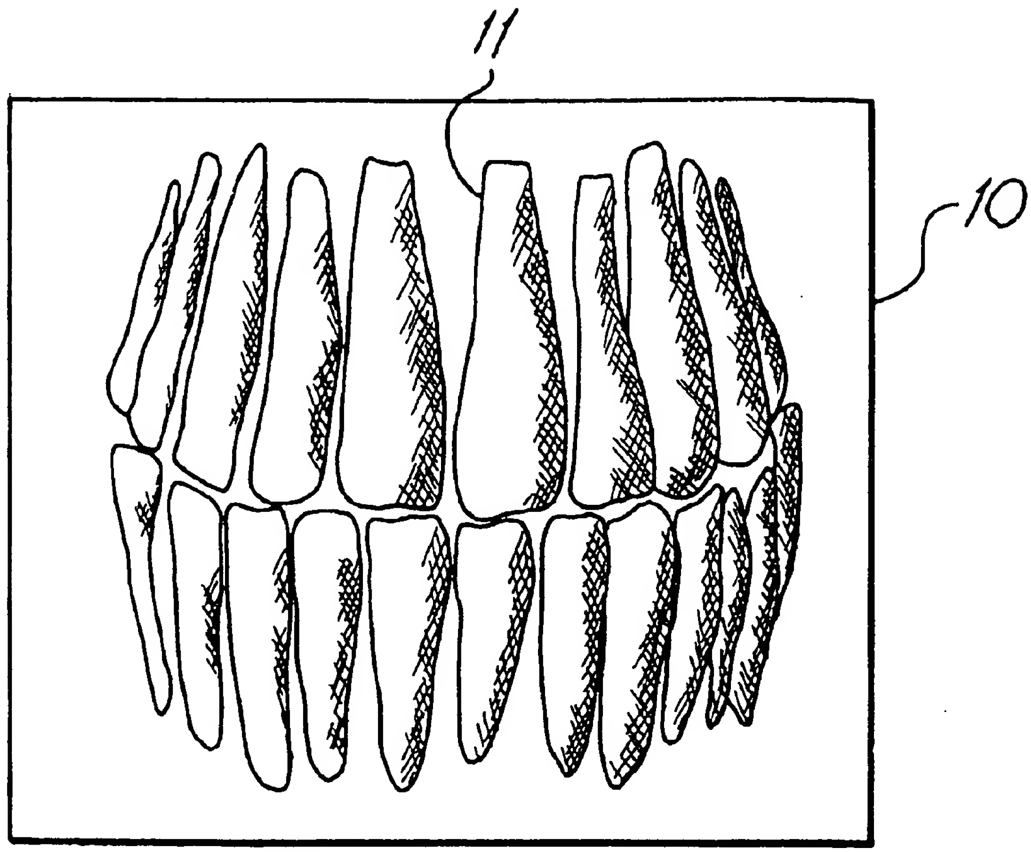


FIG. 2

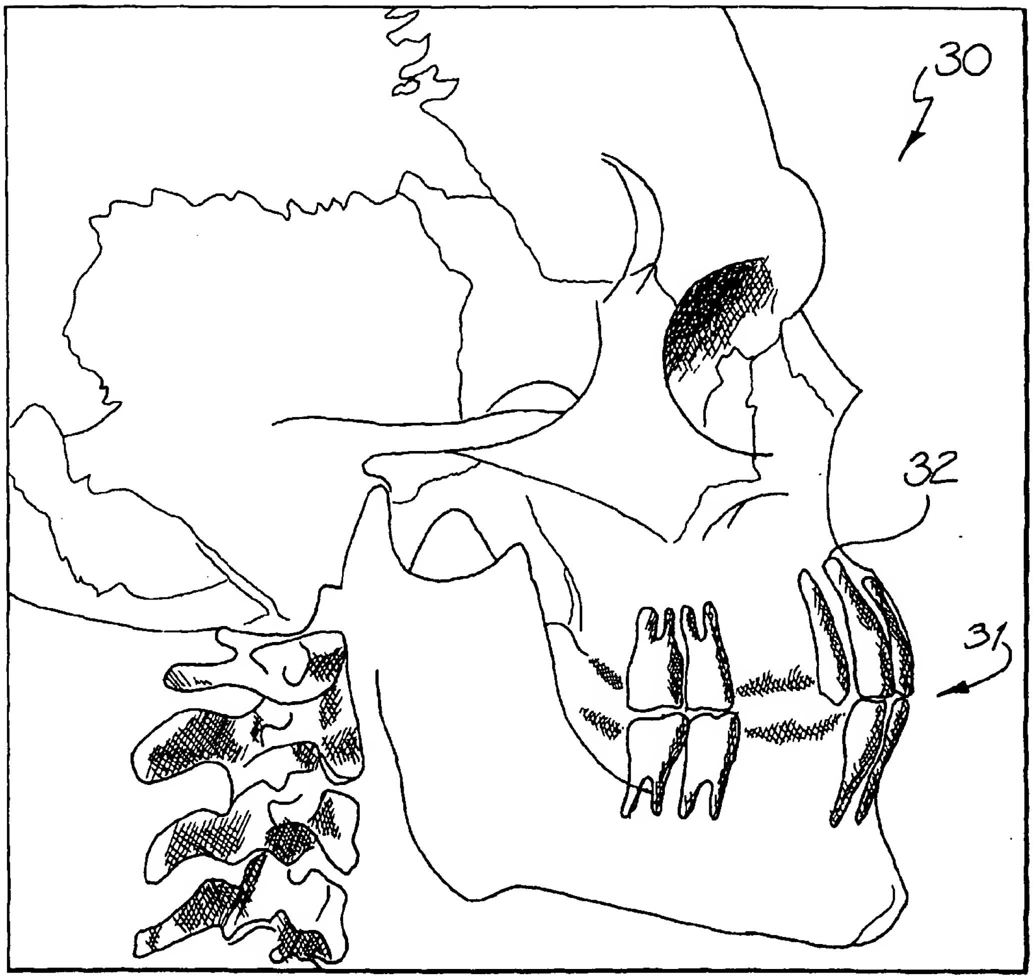


FIG. 3

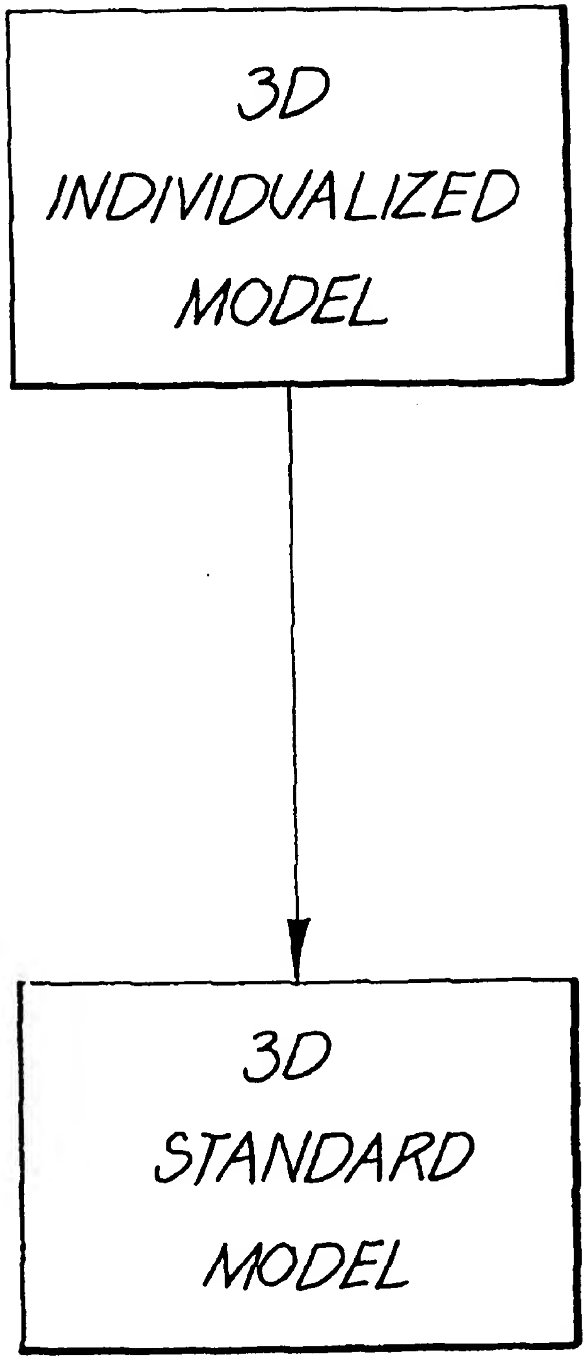


FIG. 4

METHOD FOR CREATION AND UTILIZATION OF INDIVIDUALIZED 3-DIMENSIONAL TEETH MODELS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a Continuation of U.S. patent application Ser. No. 08/785,664, filed Jan. 17, 1997, the disclosure of which is incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to the field of dental anatomy and in particular, to storing and utilising 3D computer graphic structures representative of a patient's individual tooth and jaw structure.

BACKGROUND OF THE INVENTION

At present, dentists and orthodontists, when examining patients and keeping records of their teeth structure essentially operate substantially in a world of physical three and two dimensional records. Further, the present methods of operation are unduly cumbersome. A dentist or orthodontist, when planning a treatment for a patient, will generally manually produce a plaster mould which is a 3D representation of the patients teeth. In addition, X-ray images are also used to highlight other anatomical details. The production of these 3D moulds is generally cumbersome and further results in the requirement to store the moulds handy to the treatment location for future examination. Further, a like treatment of medical images such as X-rays is also required.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an alternative form of keeping and utilising dental patient records, and allowing for the interaction there between.

In accordance with the first aspect of the present invention there is provided a 3D computer graphic model of a set of teeth, each of the teeth being manipulable by an interactive manipulation means to accurately reflect the current position of a patient's set of teeth. Preferably, the placement of the teeth is derived from corresponding images of plaster cast and/or medical images of the teeth.

Further, the computer graphic model preferably has the ability to automatically produce a sequence of images mapping movements of teeth from a first position corresponding to the patient's current state to an idealised second position.

Further, the model preferably includes the ability to add brackets to the surfaces of any tooth and to simulate the likely movements of any or all teeth under the forces produced by the orthodontic appliances. Additionally, advantageously there is provided the ability to accurately model likely teeth and jaw movements when bands etc, are utilised in conjunction with the brackets to produce regionalised forces acting on tooth surfaces. The preferred system having full interactive ability to determine the extent of forces by means of direct user input. Further, an alternative form of the invention can include the ability to measure sensor inputs and to input the measured sensor inputs into the 3D graphical model for providing simulated jaw movements of the model. Further, simulated sound output is also preferably provided, simulating or rendering the recorded or likely sound to be heard when the teeth are brought into contact with one another (dental occlusion). In accordance with a second aspect of the present invention there is provided a method of automatically determining cephalometric structures in a cephalometric radiograph which can optionally include utilising the corresponding 3D computer graphic model as aforementioned to determine positions of cephalometric structures on an X-ray image. Preferably, the system allows for interactive alteration of any and all cephalometric structures and measures.

In accordance with a further aspect of the present invention there is provided a method of keeping patient dental records comprising:

(a) providing a 3D model of a standard set of teeth which is interactively manipulable by a user;

(b) utilising said model composited over a medical image corresponding to a patient's dental structure by means of adjusting the tooth position within said model to match said medical image.

In accordance with a further aspect of the present invention there is provided a method of creating brackets and/or braces for orthodontic treatment comprising:

(a) determining an accurate individualised 3-dimensional computer graphical model of a patient's teeth;

(b) utilising said model to place at least one simulated bracket on the surface of at least one of said teeth;

(c) adapting said simulated bracket to the corresponding surface of said tooth; and

(d) utilising said simulated bracket to produce a corresponding actual bracket for utilization in said orthodontic treatment.

BRIEF DESCRIPTION OF THE DRAWINGS

Notwithstanding any other forms which may fall within the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 illustrates the steps of a first form of creation of an individualised 3D model of a patient's tooth position;

FIG. 2 illustrates an example standard 3D tooth model;

FIG. 3 illustrates the process of manipulation of the standard model in front of a corresponding X-ray image to derive a patient model for the tooth positions; and

FIG. 4 illustrates a process for interpolation between a 3D individualised model and a 3D standard model.

DESCRIPTION OF PREFERRED AND OTHER EMBODIMENTS

In the preferred embodiment of the present invention, an individualised 3D model of a patient's teeth is created from two dimensional dataset representations and a standard 3D model utilising a computer system. The preferred embodiment can be implemented utilising a standard high end Pentium (trade mark) based personal computer system running a high end operating system such as "Windows NT(Trade Marks) and a 3D modelling language modelling, for example, the standard virtual reality mark-up language (VRML). Further, a high end standard Twain compatible scanner should be provided, inter-connected to the computer, for the scanning of images.

Referring to FIG. 1, the usual 2D plaster cast model 1 taken from a patient is digitally rendered by placing it on a Twain compatible flat bed scanner or equivalent device to produce a scanned 2D image of both the upper and lower jaws. Further, the usual side medical images 2, such as X-rays, are also digitally rendered into the computer system by scanning.

A 3D "standard" model 3 for the patient is provided. The 3D standard model is represented by a three dimensional

computer graphical representation of a standard male or female patient's teeth as required. It is well known in the field of dentistry that the structure of individual's teeth in respect of their size and shapes is substantially of low variance across a general population. However, there is a high variance generally with respect to position or placement of an individual's teeth. Hence, the use of the standard 3D models is well known in clinical teaching and in practice. The 3D standard model can be created in a 3D computer graphical form as a "once off" by laser scanning a physical example of the corresponding 3D standard model or by other known techniques for entering 3-dimensional data into a computer system.

Turning now to FIG. 2, there is illustrated an example **10** of the three dimensional computerised form of the standard teeth model. Preferably, the 3D form includes the usual controls (not shown) for the location, scaling and translation of each of the upper and lower jaws. Also, preferably, controls are included for the scaling translation and rotation of each tooth **11** independently. Further, each tooth **11** can preferably be selected to be visible or invisible in accordance with a particular patient's jaw profile. Further, each tooth **11** can be made partially transparent. Further standard enhancements, such as the placement of computer graphical lighting sources to provide shading and other 3D enhanced effects which normally are of standard 3D modelling packages can also be utilized for enhanced realism.

Turning again to FIG. 1, in the preferred embodiment, the 3D standard model **3** is utilised, in conjunction with the "scanned" plaster cast model **1** and/or a profile X-ray view **2**, to produce a 3D individualised model **4** which differs from the standard 3D model **3** in a patient specific manner. The individualised 3D model can then be utilised as a patient record for treatment planning and record keeping.

The 3D individualised model can be determined from the standard model by many different techniques known to those skilled in the art of computer graphics and image processing. One form of manual orientation of teeth position will now be illustrated with reference to FIG. 4. In this case, the patient's X-ray image **30** is displayed on the computer screen as a background image for the 3D standard model. The standard model is then rotated, translated and scaled by the user so as to match the orientation of the X-ray image **30**. The individual teeth eg. **32** are then adjusted by means of translation, scaling and rotation so as to match the X-ray image. Preferably, each tooth can be made partially transparent so as to enhance the alignment of the tooth **32** with the X-ray image.

A similar process can then be carried out utilising the two dimensional scanned cast model. The cast model can be scanned in and displayed as a background image. The three dimensional computer graphic model can be overlaid over the cast model in jaw alignment, in a partially transparent form and each individual tooth adjusted so as to correctly place it relative to the cast model. Preferably, this process can be carried out for each individual upper and lower jaw separately with the other jaw being "turned off" via a suitable user interface and the tooth adjustments made. Although the aforementioned method of adjustment of the standard tooth model requires manual intervention by the experienced user, the utilisation of tooth models having a degree of transparency results in an accurate positioning of the computer graphic model relative to a patient's actual teeth position.

Upon optimisation of the 3D individualised model, to teeth positions corresponding to those of the individual patient, these are then saved and utilised as a computerised form of record for that patient.

Other forms of fusion of the 2D moulds are possible and such techniques will be known to those skilled in the art of image analysis and 3D graphics. This further includes turning off individual teeth as required.

In a further refinement, the 3D individualised model can be utilised in treatment planning to produce an improved form of treatment planning. It is often the objective in orthodontic treatment to overcome individual anomalies in an individual patient's arrangement of teeth. Hence, in a further refinement, referring to FIG. 4, the position of an individual's teeth is first measured and reflected in the 3D model, utilizing the aforementioned techniques. The location and rotation of each tooth in the individualized 3D tooth model relative to the standard model is then noted. Next, a mapping from the position of each individual tooth in the 3D individualised model **4** to the corresponding position of the tooth in the 3D standard model **3** is determined by means of a series of interpolation steps between the two models, with the distance between interpolation steps being preferably a user defined parameter.

The computer system is then programmed to "animate" the movement of teeth from the 3D individualised model **4** to the 3D standard model through the series of steps from one model to the next model, rendering each step in turn for the specialist or patient to view.

In a further refinement, utilizing the 3D computer model, accurate position sensors can be utilized to a patient's upper and/or lower jaws. The position sensors can be utilized to accurately track movement of the patient's lower jaw in opening and closing of the patient's mouth to define a motion of the lower jaw with respect to the upper jaw. This data can then be utilized for movement of the two jaws, one relative to the other. In the 3D computer graphic model, each jaw is treated separately and the lower jaw is then programmed to move relative to the upper jaw in accordance with the pathway defined by the position sensors. Accurate jaw movement tracking gives the orthodontist the ability to accurately view a patient's likely jaw movement for each corresponding movement in individual tooth arrangements thereby locating likely problems in a patient's treatment program.

In a next refinement of the preferred embodiment, a simulation of the sound of the 3D computer graphic model of the two animated jaws being drawn together is created or recorded. Although many refinements are possible, in one form, the total surface area likely to make contact between surfaces of the two jaws when brought together is calculated and an audible sound, having frequency components preferably substantially inverse to the amount of surface area being brought together is produced to simulate a corresponding actual sound. It will be understood by the expert in computer graphics that a certain degree of variation on the present theme is possible. For example, the definition of contact can be extended to a certain degree of proximity of two surfaces with an assumed degree of "play" in the surfaces being connected. Further, more accurate models are envisaged whereby a fourier analysis of actual teeth clenching is conducted and measurements made of the likely degree of contact and the profile of contact of two surfaces and the sound produced for those degrees of contact. Of course, other refinements are possible, including exaggeration of the likely sounds in order to assist the orthodontist in profiling the actual contact being made by any particular patient. Indeed, many different alterative sound formats

could be provided simultaneously with a selection being under the control of a specialist user via the usual graphical user interface.

In a further refinement of the preferred embodiment, a means can be provided for conducting automated cephalometric analysis of the 2D X-ray image of the patient. In a first refinement, the computer graphics means can be utilised for display of X-ray images with various sets of cephalometric data points displayed over the X-ray image for individual manipulation by a user of the system. The overlays can include points of interest, connected lines, splines and other curves, which can be collectively manipulated to conduct various analyses such as Bjork, Boulton's Triangle, Downs, Down Harold McNamara, Ricketts, Sterner, Tweed, Wits and Wylie cephalometric analysis. Preferably, a collection of expected landmarks for adjustment by the orthodontist is initially provided in accordance with any of the above alternative analyses. Upon selection of the desired treatment, a specialist user is able to manipulate each individual line, spline or points placed over an X-ray image structure of the patient and thereby adjust the example set of lines to customise the results of the chosen analysis. The customised analysis is preferably able to be stored and retrieved as required, with each analysis being able to be dynamically altered as required.

In a further refinement, the individualized customization of the points, curves and lines are automatically derived from the X-ray image utilising the patient's corresponding 3D model. It will be readily evident that the cephalometric analysis can be automatically conducted in a number of different ways, including directly locating the cephalometric points in the X-ray image. Alternatively, the 3D individualised model as derived in accordance with the principles aforementioned can be utilised to locate the cephalometric points and then mapped to the relevant X-ray image as located from the X-ray image of the same individual.

In a further refinement and use of the preferred embodiment, the personalised 3D computer graphic model can be utilised for the placement of brackets and/or braces thereupon. Different suitable brackets can initially be created. The chosen bracket can be individually located interactively on the 3D model with the bracket's size, shape and position being adjusted by the expert orthodontist. Upon determination of a final position of brackets, the bracket can be individually structured to contour a corresponding surface of the tooth so as to minimise stress variance across the tooth or to minimise the possible damage to the tooth as a result of placement of each bracket but providing a better fit on the tooth surface. The individualised 3D model can then be utilised to create an individualised bracket with accurate measurements with the surface of each bracket accurately profiled to match the corresponding surface in the individualised tooth. The bracket structure can be output in a standard stereo lithographic format (STL) and later used to create a corresponding customized brackets/braces.

In a further refinement, the 3D computer graphic model and corresponding brackets can further include bracing rods etc, each having variable tensions and forces and the 3D model utilised to accurately project the movement of each tooth under the expected structural load. Means can then be provided for variation in the tension of braces, bands etc, and, through interactive feedback, the expert user can determine an individualised orthodontic treatment for the utilisation by a particular user.

It will be obvious to those skilled image processing and three dimensional computer graphics that many variations of the aforementioned embodiments are possible utilising the latest in three dimensional computer graphics techniques. Further, it would be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

What is claimed is:

1. A method of determining a dental record of a dental patient's teeth in a computer system comprising the steps of:

(a) imaging a patient's teeth so as to produce at least one two dimensional image of the patient's teeth;

(b) visually superimposing an initial 3-dimensional computer graphic model of a set of teeth having independently manipulable teeth objects onto said two dimensional image;

(c) interactively adjusting at least one of the position, orientation or scaled size of said manipulable teeth objects so that they are aligned with said two dimensional image; and

(d) storing the adjusted computer graphic model of said set of teeth as said dental record.

2. A method as claimed in claim 1 wherein said two dimensional image comprises an X-ray image of said patient's teeth.

3. A method as claimed in claim 1 wherein said two dimensional image comprises a scanned image of a three dimensional impression made of a patient's teeth.

4. A method as claimed in claim 1 wherein said 3-dimensional computer graphic model includes an adjustable degree of transparency and said step (c) further includes adjusting the degree of transparency of at least one of said manipulable teeth objects.

5. A method as claimed in claim 1 further including the step of:

(e) utilizing said dental record as an initial state in an iteractive series of states having different orientations or positions of said manipulable teeth objects.

6. A method as claimed in claim 1 wherein said iteractive series of states include an initial state and a final state and wherein the series of states between the initial and final states are automatically generated.

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